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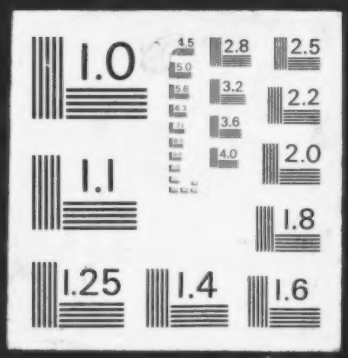

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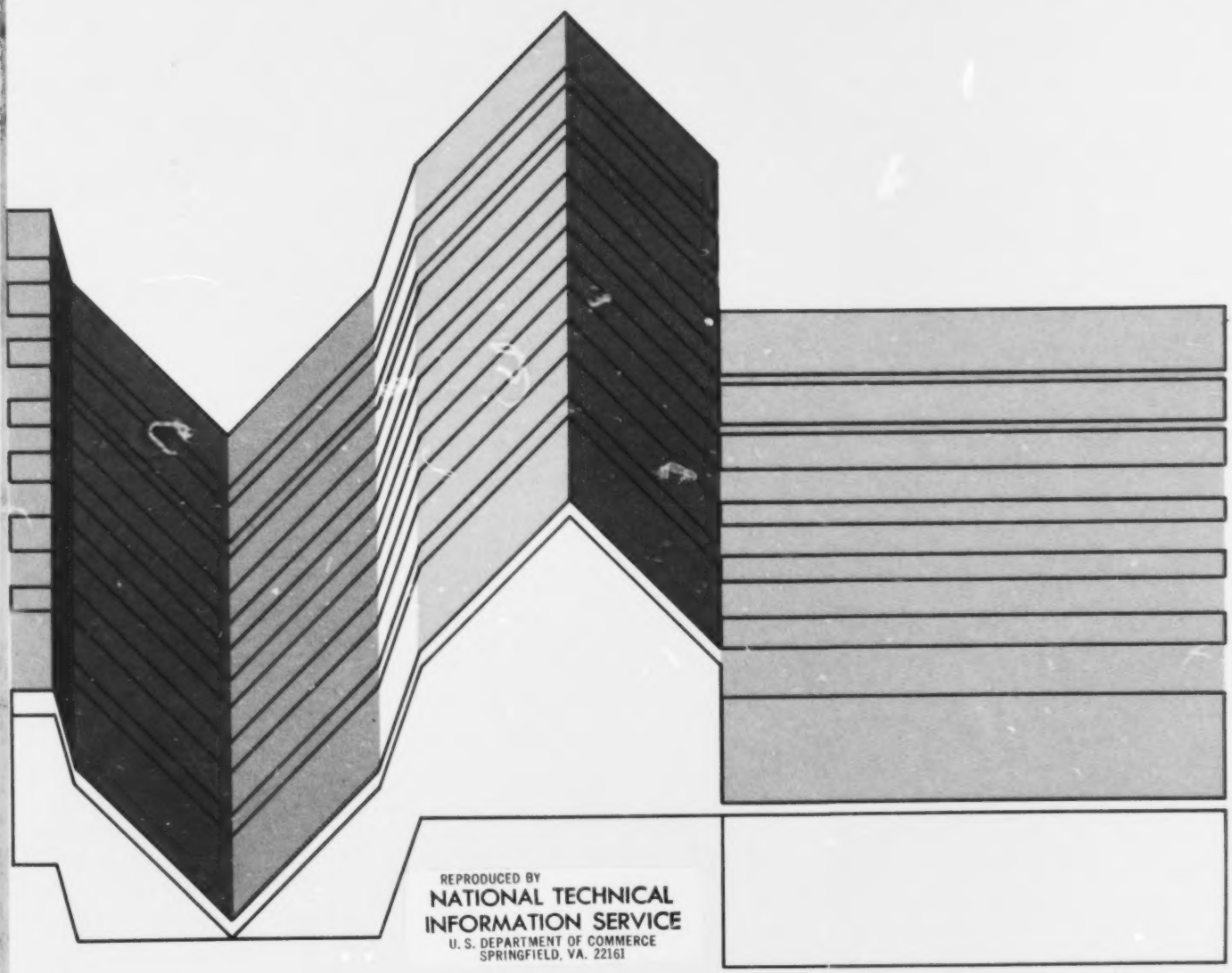

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16. ABSTRACT

The results described in this report represent but a few of the projects supported by the Office of Research and Development in 1977. The program ranges from direct support to EPA's regulatory functions, such as cancer assessment and drinking water purification, to investigations of long-term phenomena, such as the ozone layer analyses. It ranges from technologies to clean up car exhausts to technologies to clean up power plant fumes, and from studies of how cells react to carcinogens to studies of how people react to energy development activities. In this report, you will find studies on cars, cancer, energy, water, pesticides, cake ovens, ozone, cheese and waste. This is just a sampling of the projects underway, selected for reviews here because they represent breakthoughs in research, fill a practical technological void, are inherently interesting, or have implications for the future.

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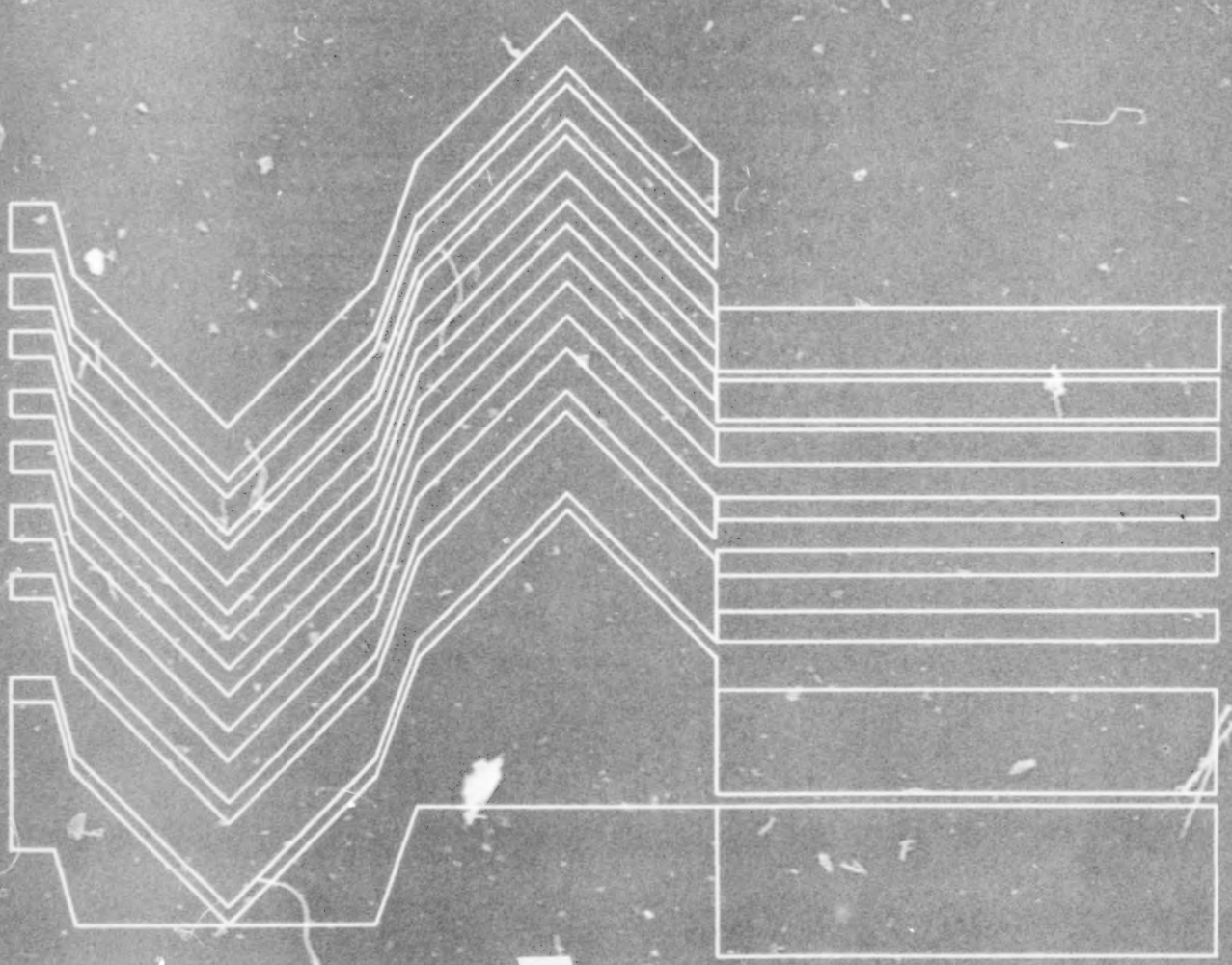

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DISCLAIMER

This report has been reviewed by the Office of Monitoring and Technical Support, U.S. Environmental Protection Agency, and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

introduction

1977 research highlights

This summary of research describes a cross-section of the work done in 1977 by the EPA Office of Research and Development. It is by no means a complete, in-depth report on all the activities of ORD, which sponsored more than 1,900 projects in 1977. What it does provide is a sampling of ORD projects, selected for review here because they represent breakthroughs in research, fill a practical technological void, are inherently interesting, or have implications for the future.

The Environmental Protection Agency is charged with protecting human health and the environment through promulgation and enforcement of standards and regulations. The backbone of any regulation is the research which goes into its design. Auto emission standards, for example, must be based on health, pollution and cost data. Water contaminants or carcinogens must be carefully identified so that they can be effectively regulated. The importance of scientifically precise research in this arena cannot be overstated. For example, if a substance such as a pesticide is identified as a serious hazard, its production and use can be banned. Such a ban can have a disruptive effect upon a major industry or sector of the economy. If, on the other hand, the substance and its hazard are not identified, many people can be exposed to extreme and unnecessary risk.

ORD conducts the major EPA research effort and establishes the best possible scientific foundation as the first step in the design of standards and regulations in support of their ultimate enforcement as law. For instance, as you will read in a later section, ORD played a key role in the development of preliminary environmental guidelines which should help stimulate the development of geothermal energy by removing some of the attendant environmental control uncertainties.

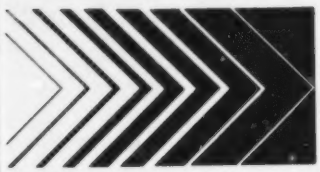
Beyond providing support to EPA's regulatory function, ORD has another concern. That is, to provide data and expertise in support of state and local enforcement of regulations. As part of this role, ORD conducts research into improved methods for analyzing and monitoring pollutants, and develops new technologies that contribute directly to the prevention and treatment of environmental pollution.

In its research, conducted by offices and laboratories throughout the country and by numerous contractors and grantees, ORD is concerned with a wide range of subjects. The studies by ORD scientists take them to every part of the United States, from geothermal geysers in California, to steel plants in Pennsylvania, to the commercially rich waters of Chesapeake Bay. Much of this research is the behind-the-scenes methodical analysis necessary for rigorous scientific validity. In one sense, the topics of this report are as diverse as is the program which they describe. Some results are directly to support regulation, and some are for options to meet regulations. Others are in response to an immediate public danger, while still others are a step to understanding the ecosystems around us. In this report alone, you will find studies on cars, cancer, energy, water, pesticides, coke ovens, ozone, cheese and waste. It is hoped that this survey of research topics will interest the reader, and provide some sense of the work and the mission of ORD.

EPA Legislative Mandates

Public Law No.	*Title*	*Year Passed*
78-410	Public Health Service Act	1944
89-272	Solid Waste Disposal Act	1965
91-190	National Environmental Policy Act	1969
91-604	Clean Air Act Amendments	1970
92-500	Federal Water Pollution Control Act Amendments	1972
92-532	Marine Protection, Research and Sanctuaries Act	1972
92-574	Noise Control Act	1972
92-583	Federal Insecticide, Fungicide Rodenticide Act Amendments	1972
93-523	Safe Drinking Water Act	1974
94-469	Toxic Substances Control Act	1976
94-580	Resource Conservation and Recovery Act	1976

cancer

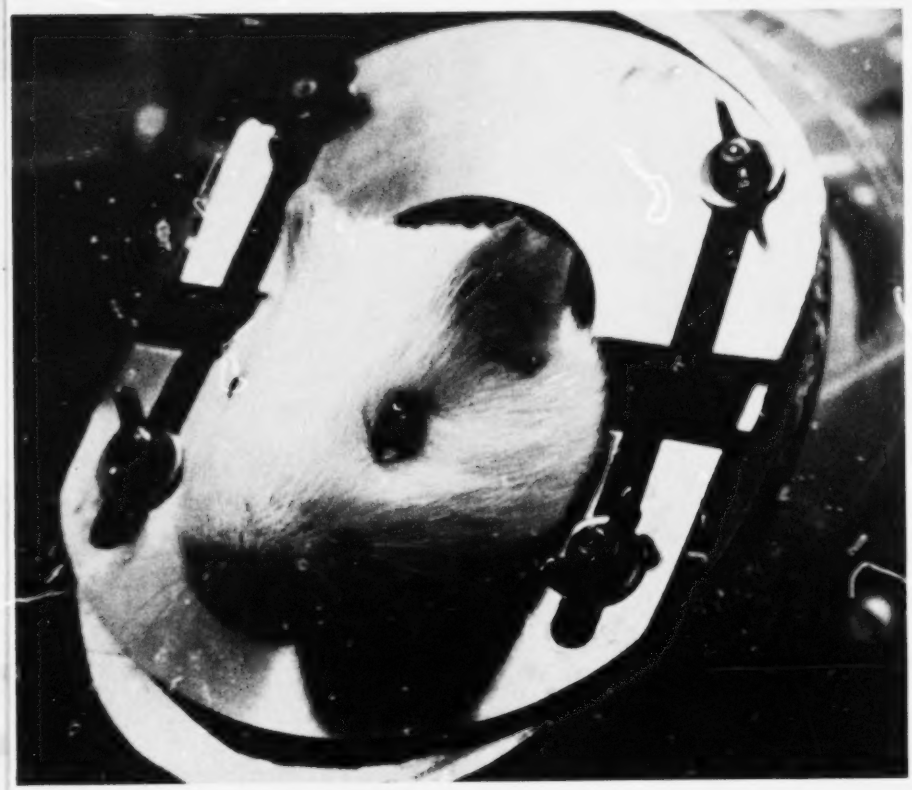


ORD seeks ways to reduce the risk of cancer from exposure to environmental carcinogens

It is estimated that 60% to 90% of human cancer is caused by physical and chemical agents in the environment. Within ORD, the Carcinogen Assessment Group (CAG) has recently been established to identify carcinogens in the environment, and to estimate the population at risk of exposure.

The task of identifying carcinogens is an exacting one. Although there are generally accepted principles of carcinogenicity, much knowledge and theory is still evolving, and there is a relatively small number of experts, when measured against the growing need to respond to carcinogenic hazards. The CAG has, therefore, sought help from other experts and institutions involved in cancer research—most notably, from the National Cancer Institute and the National Center for Toxicological Research.

To determine the carcinogenic potential of a suspicious substance, the CAG collects and examines relevant data. The best evidence that an agent is a human carcinogen is provided by epidemiological data, backed by confirmatory animal tests. However, epidemiological data directly linking a substance to cancer in exposed humans is usually lacking, and, in practice, most judgments on carcinogenicity rest on animal tests showing tumor production in exposed rats and mice.



New Controls on Pesticides

A key agency objective for CAG is a review of the safety, with regard to carcinogenic hazard, of the approximately 30,000 pesticides currently registered in the United States. Some 50 pesticides under suspicion as carcinogens were referred to the CAG for review. In its reviews, the CAG singled out 18 pesticides which either produced an excessive number of tumors in laboratory animals or had epidemiological data directly relating the substance to human cancer. Subsequently, for most of the 18 chemicals, EPA's Office of Pesticide Programs is issuing a Rebuttable Presumption Against Registration (RPAR), the first step in deciding if a pesticide's registration should be canceled.

One pesticide challenged as a result of CAG study was dibromochloropropane, or DBCP. In the summer of 1977, workers in plants producing the pesticide were found to have significantly reduced sperm counts. CAG analyses of bioassay tests showed that DBCP produced atrophy of the testicles and malignant tumors in laboratory animals. In October 1977, EPA temporarily banned the sale and use of DBCP, and currently is seeking to make the ban permanent.

CAG scientists also took part in the administrative hearing on chlordane and heptachlor. This hearing began two years ago, when manufacturers decided to challenge the proposed cancellation of these pesticides. CAG prepared a full risk assessment of the impact on public health of chlordane and heptachlor, and submitted it, along with an independently produced economic impact report, as evidence in the hearing. These reports brought previously doubtful issues into sharper focus, and provided strong evidence in support of the cancellation of these two pesticides.

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CAG Assessments Will Continue to Cover a Broad Range of Toxics

In Support of:	*Delivered FY-77*		*Predicted FY-78*
Office of Pesticides Programs			
PRE RPAR Reports	Endrin	Dimethoate	Ethylene Dibromide
	Safrole	Maleic Hydrazide	Carbon Tetrachloride
	Triallate-Diallate	PCNB	Creosote
	BAAM	EDBC	Coal Tar
	BHC	Ethylene Oxide	Piperonyl Butoxide
	Lindane	Dibromochloropropane	Arsenicals
	Pronamide	Cadmium	DDVP
	Toxaphene	Perthane	Rotenone
	Paraquat	Dioxins (2,4,5-T)	Trichlorophon
	Monuron	Carbaryl	Dimulin
Review of Rebuttal	Endrin		DBCP
	Chlorobenzilate		Pronamide
			Lindane
			BAAM
			Diallate
			Toxaphene
Full Risk Assessments	BAAM		Chloroform
	Kepone		Chlorobenzilate
	Chlordane/Heptachlor		Endrin
	Nitroamines		Toxaphene
	Safrole in dog repellant		Pronamide
	Dibromochloropropane		
	Ethylene Dibromide		
Office of Air Quality Planning and Standards			
	Benzene (preliminary report)		Vinyl Chloride
	Arsenic (preliminary report)		Vinylidene Chloride
	Coke Oven Emissions (preliminary report)		Coke Oven Emissions
			Benzene
			Perchloroethylene
			Cadmium
			Arsenic
			Radio-actives
			Polycyclic Organics
Office of Water Supply and Office of Water Planning Standards			
			Haloforms
			Carbon Tetrachloride
			Review of 65 criteria documents on toxics PBB(II)
Regional Offices			
	Carcinogens in Philadelphia Wastewater (III)		PBBs (II)
	Trichloroethylene (II)		Toxic Chemical Prioritization (II)
	Nitrosamines (V)		Vinyl Chloride (IX)

Air Pollutants

For EPA's Office of Air Quality Planning and Standards, CAG has evaluated the possible carcinogenicity of several chemicals including benzene and arsenic. The CAG has calculated specific levels of risk in relation to exposure to air pollutants for use by the Agency in devising air pollution standards to limit human exposure.

Water Quality

For EPA's Office of Water Supply, CAG has evaluated the risks from chloroform contamination of drinking water. This evaluation played a key role in, and is part of, the EPA's proposed drinking water standards for trihalomethanes. In addition, CAG is currently assisting EPA's Office of Water Planning and Standards in a review of guidelines designed to control the effect of 65 toxic chemical pollutants, many of which are suspected carcinogens, on water quality.

Radiation

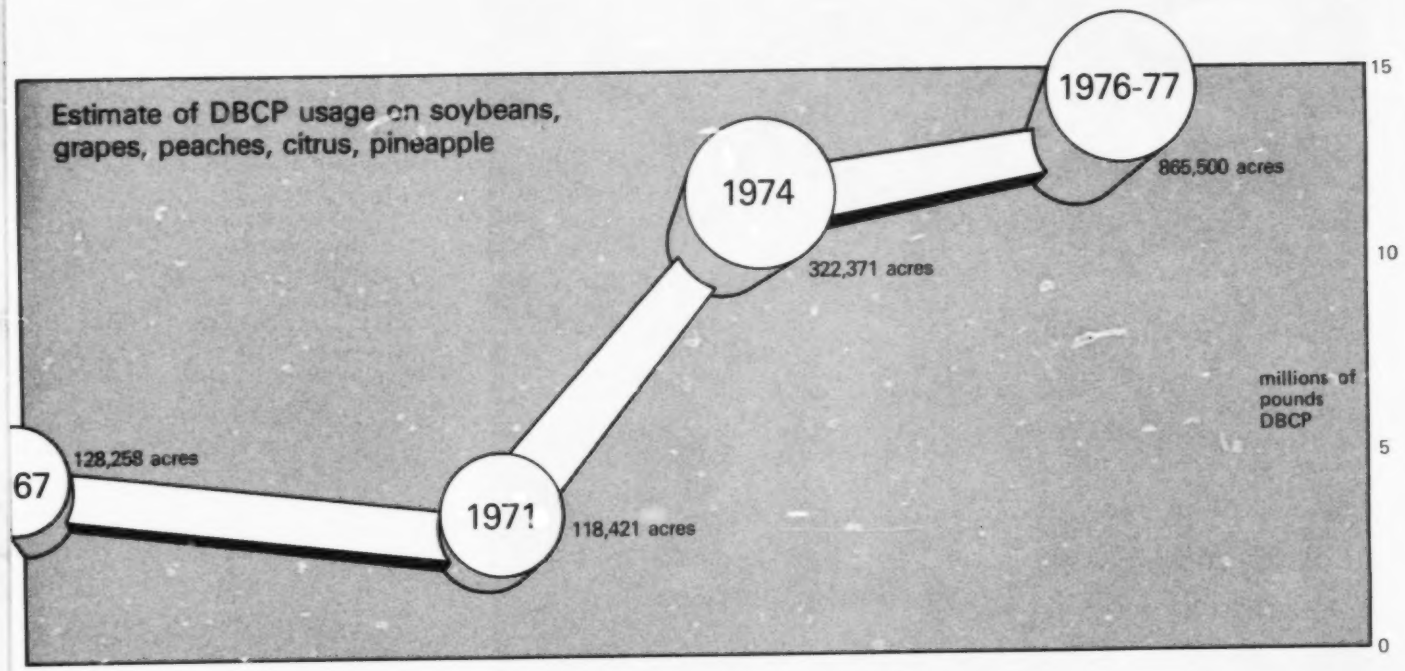
CAG is also concerned with radiation risks, and the Group is currently assisting the EPA Office of Radiation Programs in the development of guidelines to define exposure limits to transuranium elements.

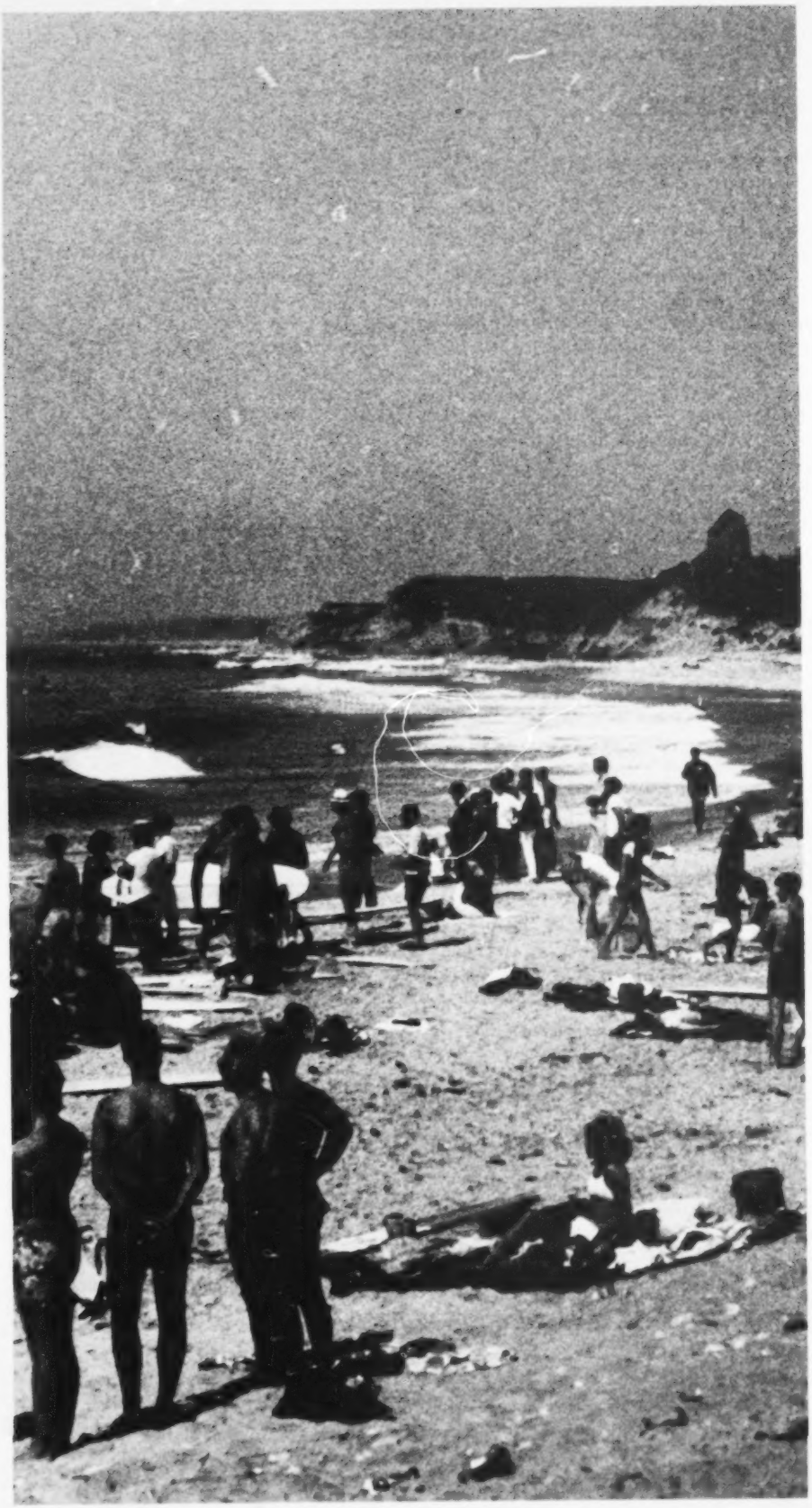
Regional Offices

EPA Regional Offices call on the Carcinogenic Assessment Group to investigate suspected local pollution from environmental carcinogens. CAG responds and helps the Regional Offices to determine whether a local health hazard exists.

1977 was the first year of operation for the Carcinogenic Assessment Group. It is now clear that the demand for carcinogen risk assessments will continue to grow, and that there will be a need for the activities of the Group to expand. Full health risk assessments are required for a number of chemicals currently being considered for regulation. And, under new legislative mandates to control toxic substances in the environment, the EPA needs to determine the carcinogenicity of a large number of substances.

The results of CAG's work, except for proprietary data, are available to the public in a year-end summary containing all the technical reports produced during 1977.





ozone

Human activities may damage Earth's protective ozone layer

ULTRAVIOLET RADIATION causes flecking of leaves (above). Exposure also stunts plants (below, center and right) as compared with unexposed plant (left).

Concern has mounted recently over the inadvertent modification of the Earth's ozone layer. Stratospheric ozone is the planet's primary shield against intense, biologically harmful solar ultraviolet radiation. This radiation, which may cause skin cancer in humans and changes in plants, may also affect climate and weather patterns. Evidence indicates that this ozone layer is being depleted and that people, through the discharge of ozone-destroying gases, may be responsible.

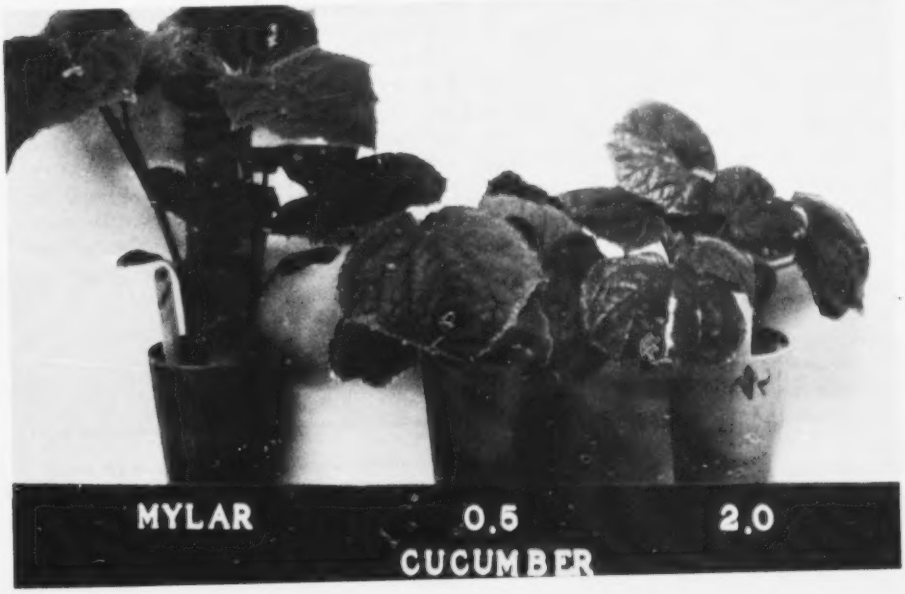
In 1976, the Federal Council on Science and Technology asked EPA to serve as lead agency in a federal interagency program of Biological and Climatic Effects Research (BACER). In response, ORD joined with other EPA offices and federal agencies to explore the possible effects of ozone depletion on the Earth's life forms and climate.

The Clean Air Act Amendments of 1977 further defined this task by mandating the FPA to mount a broad research program to determine: the effects of ozone depletion on public health and welfare, the probable causes of such effects, the methods of avoiding human-caused ozone depletions, and the best ways to regulate or control ozone-depleting activities. ORD's role in this research is to coordinate the production of adequate, scientific data which will provide a sound scientific basis for making decisions to regulate (or not to regulate) ozone-depleting activities.

The BACER program is focused on collecting, analyzing and improving data to support strategies for controlling ozone depletion. Efforts have included both laboratory simulations and tests in direct sunlight. Researchers measured the effect on plants and animals of increased ultraviolet light in the biologically important 290- to 320-nanometer wavelength range (UV-B). Light in this range is filtered by normal atmospheric ozone concentrations but tends to penetrate a reduced ozone layer.

Health Impacts

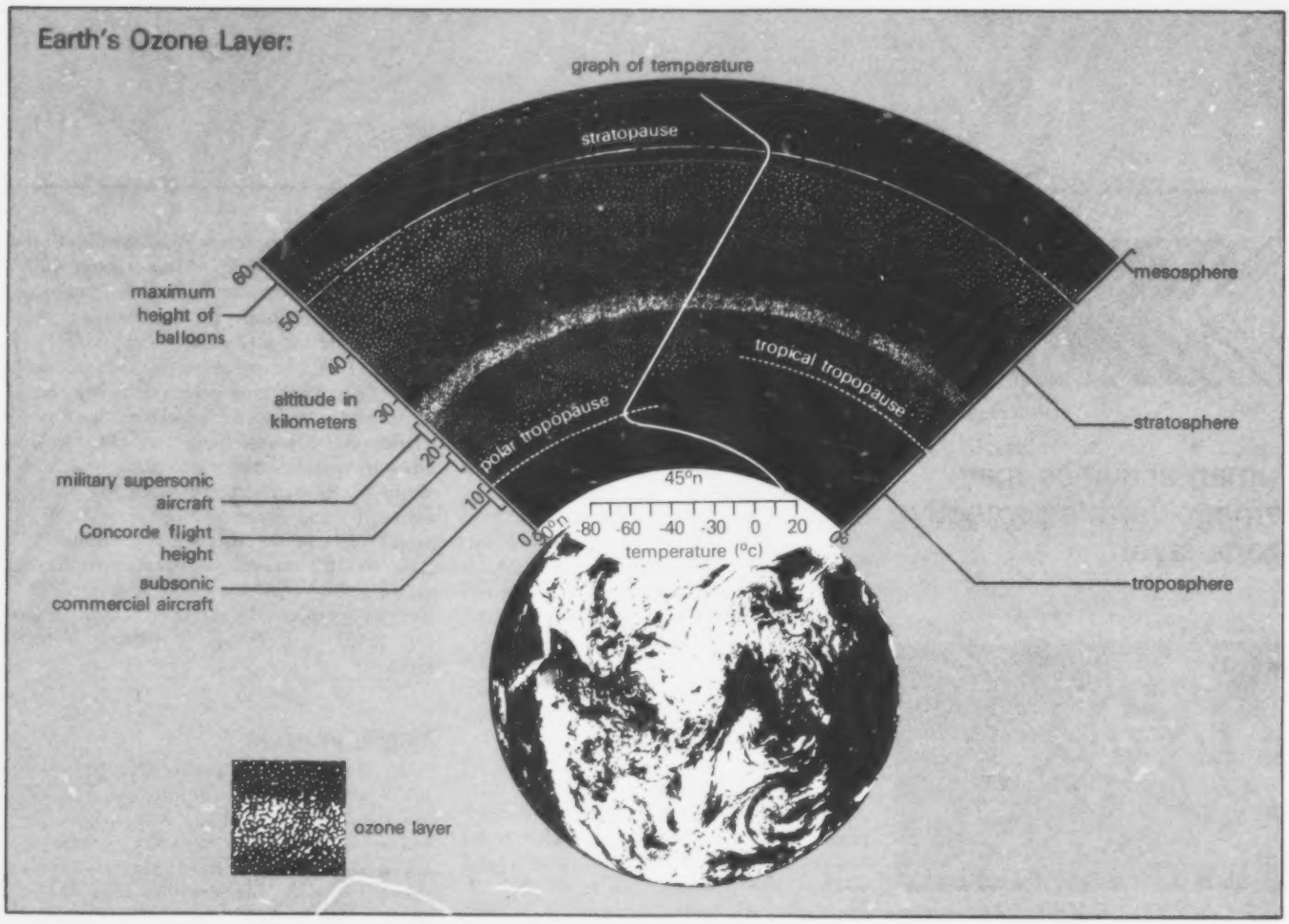
In studying the relationship between UV-B and skin cancer in humans, BACER investigators found high correlations between exposure to naturally occurring UV-B and the incidence of skin cancer in those exposed. Investigators also found that, between 1950 and 1970, the incidence of skin cancer and malignant melanoma has been increasing among Caucasians. The mortality rate from malignant melanoma has also been increasing.



Ecological Effects

Photosynthesis is the mechanism that captures the sun's energy and makes it available to all of Earth's life forms. BACER studied the effect of UV-B on photosynthesis and found that even low levels of UV-B inhibited photosynthesis in some land and water plants. Soybeans and watermelons exposed to UV-B in both laboratory and outdoor experiments became stunted, with leaves that were bleached or discolored.

BACER scientists exposed eggs and larvae of commercially important shrimp, crab, and mackerel to various levels of UV-B. Irradiation with UV-B produced lesions in the brain tissue of larvae of Pacific mackerel and anchovy, and tissue destruction in shrimp. In ecosystem studies, UV-B caused dramatic shifts in community structures. For example, the



survival rate of pigmented species of bacteria was increased in irradiated areas; this bacteria species is suspected of being toxic to some plankton and damaging to plankton ecosystems. The implications of such damage to plankton are vast indeed. Planktonic algae produce a major portion of the world's primary biomass and generate a substantial share of the Earth's oxygen. UV-B destruction of planktonic algae could create an enormous ecological imbalance and could disrupt primary food and oxygen production in the seas with wide-ranging implications for terrestrial life.

Climatic Effects

Recent research findings have shown that ozone depletion can have two major effects on climate: (1) increased transmittance of ultraviolet and visible radiation tends to warm the lower atmosphere and the surface of the earth; and (2) the depleted ozone layer allows more infrared radiation to escape from the earth's surface, thereby reducing its temperature. The net result of these two effects is currently being studied. Initial indications are that, for every 10% reduction in stratospheric ozone, the Earth's surface temperature could decrese by 0.1° to 0.2°C, and local stratospheric temperatures could decrease by as much as 2° to 3°C. This, in turn, may cause significant atmospheric disturbances, changes in weather patterns, and additional surface climatic effects.

Measuring UV-B

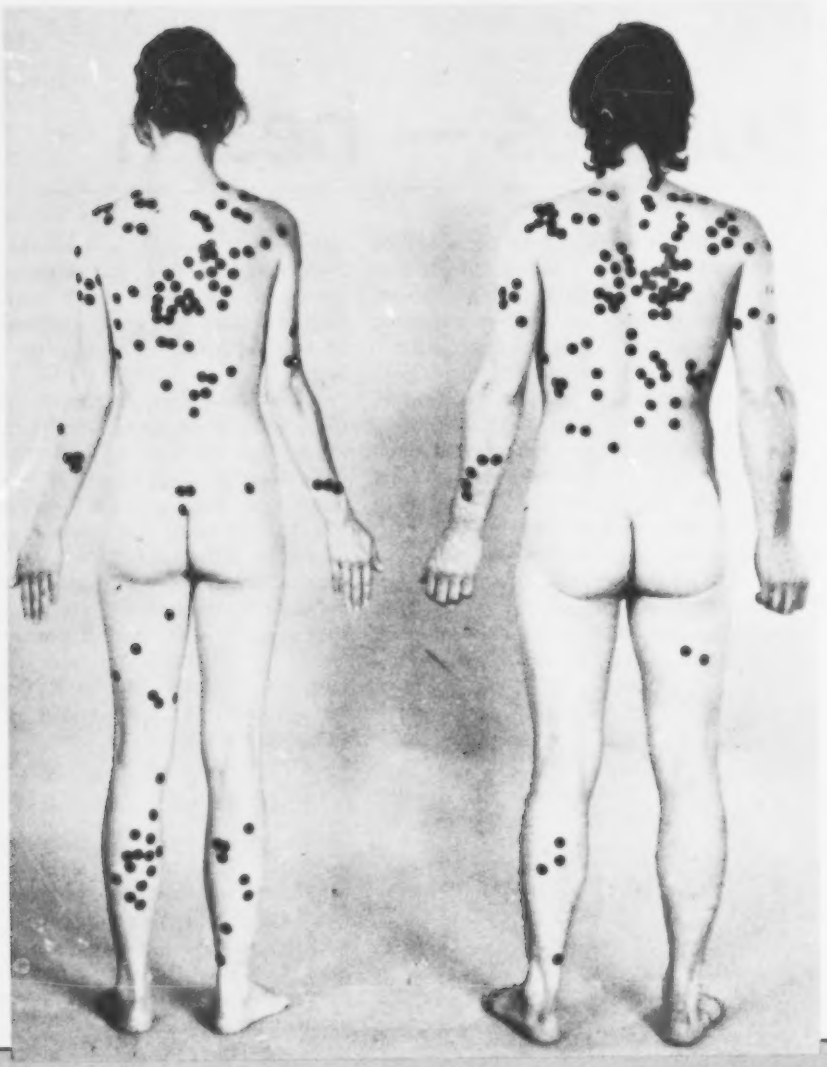
BACER is helping to expand the National Oceanic and Atmospheric Administration's monitoring network to measure solar radiation at different latitudes on the earth's surface. Current findings are that annual UV-B at latitudes in the southern United States (Florida to Texas) is about twice that in North Dakota, but that summer UV-B received at these two latitudes is about the same.

Future Plans

In the coming year, the BACER program will continue to study the effects of ozone depletion and increased UV-B radiation. The ecological effects of UV-B will be further investigated and quantified and the consequences of possible global and regional climate changes will be assessed. In addition, research on skin cancer will be extended, instrumentation to measure and monitor UV-B will be refined, the costs and impacts of controlling ozone depletion will be evaluated and the agricultural impacts of resultant climatic changes will be estimated.

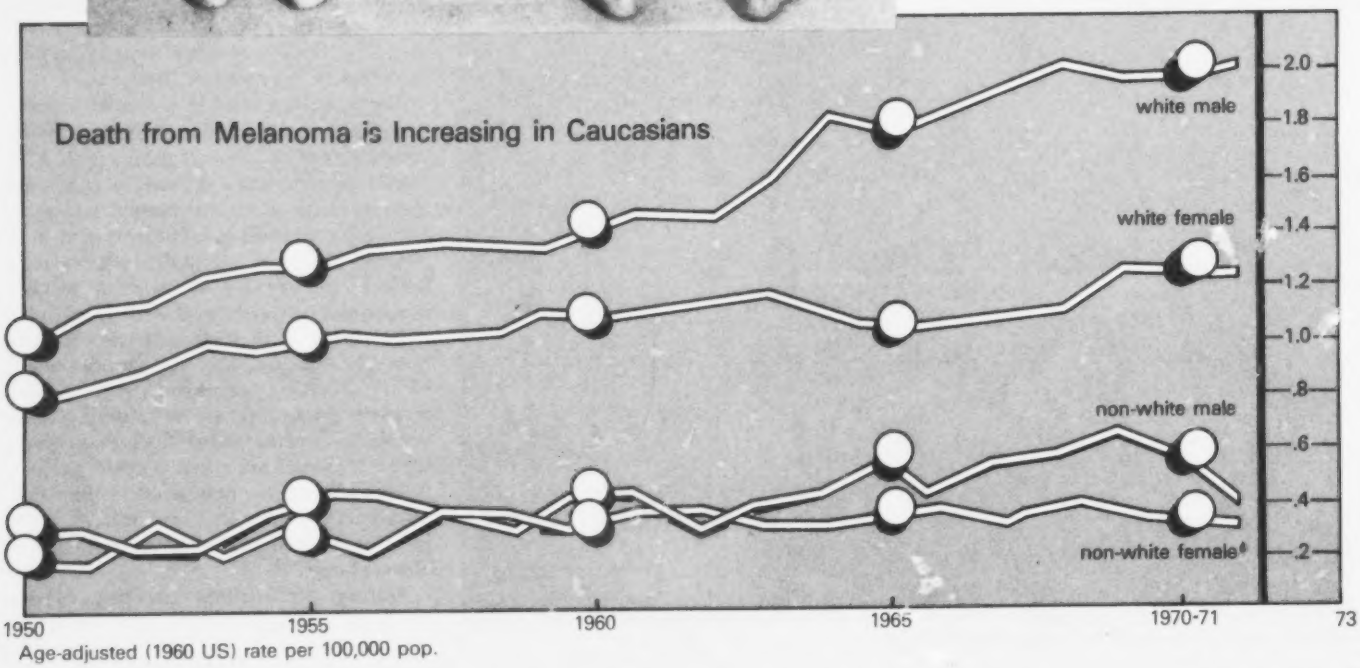
The following ORD component contributed to the research described above:

OFFICE OF HEALTH AND ECOLOGICAL EFFECTS



SKIN CANCER SITES: The figure shows sites of origin of melanoma skin cancer in 534 males and females. There is predominant localization of sites to areas of skin that are constantly exposed to sunlight (face and lower legs in females) or to body areas that are intermittently exposed (trunks and legs of males). Also observe the virtual absence of melanoma in body areas that are covered (bathing suit areas).

One should exercise caution in interpreting such information even though epidemiological studies do show high degrees of correlation with solar exposure. As yet no direct cause and effect relationship between solar exposure and human skin cancer has been proven experimentally.



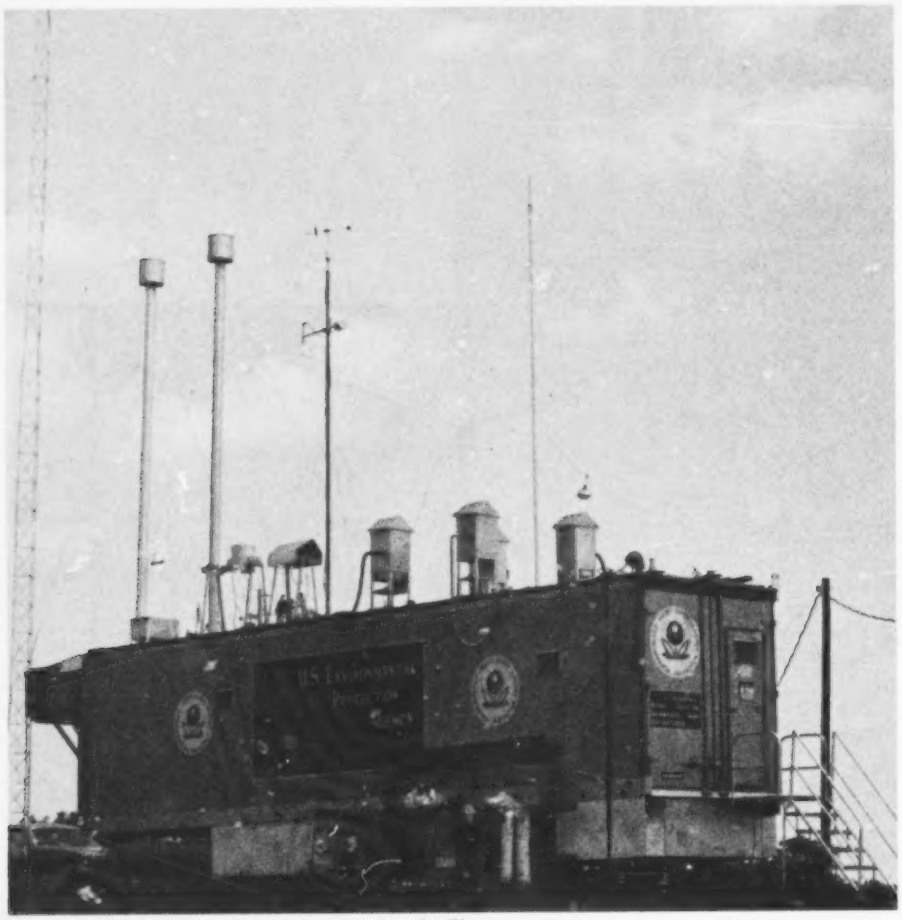
sulfates — health

New ORD data complicates, deepens understanding of relationship between sulfates and health

Atmospheric sulfates have been studied intensively since 1974 when reports first indicated that sulfates may have serious effects on health. The studies indicated that low sulfate levels may produce a variety of respiratory health problems, including aggravated asthma, bronchitis, and decreased lung functions in children. The sulfates of concern include acids such as sulfuric acid and ammonium bisulfate, neutral metallic sulfates, adsorbed SO_2 and other exotic sulfur compounds.

The sulfate problem is an increasingly important issue because of the tie between sulfate sources and the production of energy. More than half of all the atmospheric sulfates in this country may come from power plant smoke plumes. Significant sulfate concentrations are known to occur in many parts of the United States and are particularly heavy in the industrial areas east of the Mississippi.

Given these facts, the need for control of sulfates is apparent. However, EPA is aware that insufficient understanding of the sulfate problem exists. Thus, ORD has taken on the task of developing the scientific information necessary to help determine if atmospheric sulfate standards for cleaner air should be established. The program emphasizes three complex topics: (1) atmospheric processes that create or intensify sulfates from stack plumes, (2) health effects attributable to sulfates, and (3) technologies to control sulfur discharges into the air.



ORD's mobile research and monitoring facility.

Health Effects

The health problems identified in the early EPA Community Health and Environmental Surveillance System (CHESS) reports are subject to controversy among scientific authorities. Many scientists believe the CHESS results are not conclusive proof that sulfates cause such significant health problems. Others believe that sulfates only contribute to a potential health problem. ORD's health effects research is intended to help resolve these issues.

Early sulfate health effects research under ORD sponsorship consisted mainly of toxicology studies on guinea pigs. After 1974, the emphasis shifted to other animals to help calculate human exposure/response relationships. Sulfuric acid in its aerosol form is of particular concern because its toxicity varies with weather conditions, aerosol particle size, and mass concentration, as well as with the duration of exposure, age, and general health of a receiving organism. The clinical research programs are considering these variables as they relate to human exposures. Included are those aerosol particles most likely to be deposited in the lungs, pulmonary responses, mucociliary transport of aerosol particles, and changes in blood chemistry.

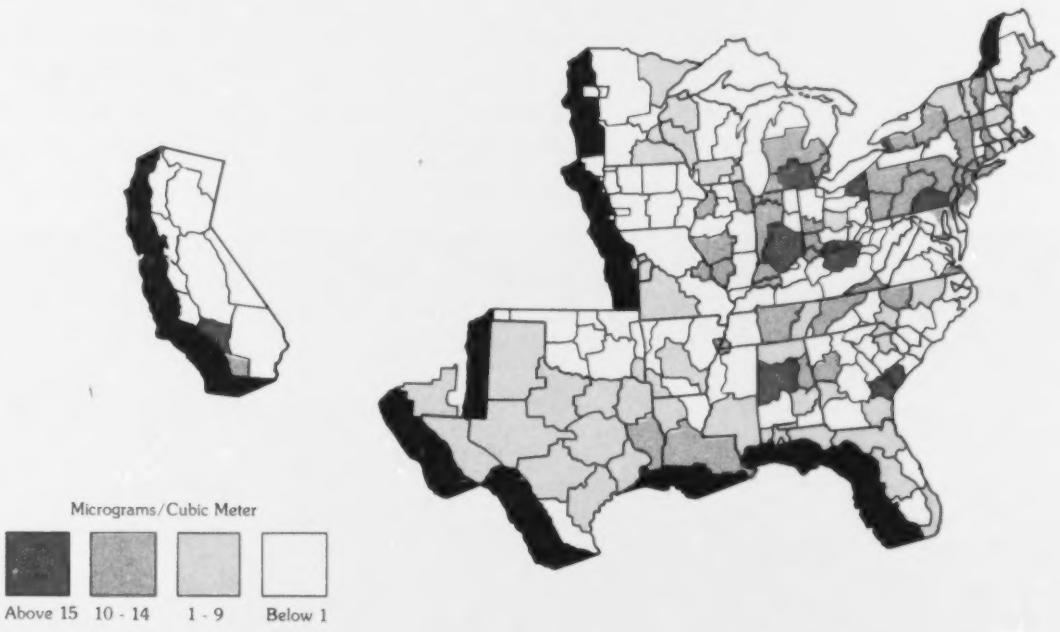
During 1977, this exacting clinical research has compiled data on the health effects of sulfuric acid and various sulfate

Another sulfuric acid experiment during 1977 investigated the combined effects of carbon particles (e.g., soot) and the acid. It was found that mice undergoing long-term simultaneous exposure of carbon and carbon particles had more pronounced morphological changes in the respiratory tract than when exposed to just sulfuric acid alone.

An experiment dealing with metallic sulfates also produced significant results in 1977. Rabbit alveolar macrophages were exposed to the sulfate and chloride salts of seven metals to determine relative cellular toxicities. The results of the experiment showed that both the sulfate and chloride of each metal had about the same toxicity, but that the toxicities varied between metals, and between different sulfate salts. These results support an earlier supposition that the sulfate of a metal may not constitute the principal health agent, but that its particular compound may be the principal cause of adverse health. For example, zinc ammonium sulfate was found to be more toxic than zinc sulfate. Since most sulfur is emitted as SO_2 and transforms into a sulfate in the atmosphere, there is little hope of controlling what sulfate is formed. However, if some types of sulfates are found to be innocuous, there may be no need to control their direct emission from those few sources which may emit that particular compound.

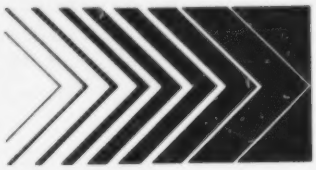
salts. One ORD project studied the effect of the combined action of sulfuric acid aerosol and ozone on the susceptibility of animals to an aerosol of respiratory microorganisms. Nether pollutant alone caused a mortality increase. There was, however, a significant increase in mortality when the exposure to ozone immediately preceded that of the acid. Thus, the studies indicate that these pollutants can interfere with host defense processes and make animals more vulnerable to infections.

Sulfate Concentrations, 1974



First Year ITA Air Quality Impact Assessment Model and Results, January 1977, Teknekron, Inc.

sulfates in air



Investigations begin to reveal how sulfates are created, how they travel, what forms they take

Although fossil fuel combustion in utilities and industry is the major source of sulfates in America's air, few sulfates are emitted directly from the plants.* Instead, the most common sulfur compound in the exhaust gas, sulfur dioxide (SO_2), is transformed into sulfate in the atmosphere through a series of complicated reactions including oxidation by constituents of photochemical smog. These reactions are induced by a variety of atmospheric conditions such as the ambient air turbulence, the presence of other pollutants that catalyze the conversion of SO_2 to sulfates, and the length of time the SO_2 is airborne.

Perhaps the most definitive study of SO_2/sulfate transport to date is the ORD's Midwest Interstate Sulfur Transformation and Transport study (MISTT). As part of the MISTT study, air sampling to determine the fate of SO_2 and the sulfates has shown that emissions from smokestacks, power plant plumes and general urban pollution can contribute to sulfate air pollution a hundred or more kilometers away from the source of the SO_2. Thus, the government authority that regulates the emitting source may be outside of the jurisdiction where the major sulfate impact occurs.

Other factors of the SO_2-to-sulfate conversion process are problematic. One past strategy of power plants to meet ambient air quality standards for SO_2 had been to build taller smokestacks, thus allowing ambient air to dilute the SO_2 concentration more thoroughly before it reached the ground. But the conversion of SO_2-to-sulfate aerosol in the plumes, which is slow in the initial phase, increases as ambient air mixes with the plume. More SO_2 is thus available in the atmosphere for conversion to sulfates and more SO_2 atmospheric residence time means more sulfate formed. Therefore, as tall stacks reduced ground-level SO_2 concentrations, they also increased atmospheric sulfate formation. These atmospheric sulfates may contribute to acid rainfall, notably in the eastern United States and Canada, and are believed to contribute significantly to haze and the general loss of visibility associated with air pollution.

The ORD research on sulfate transport and transformation is aimed at achieving a fuller understanding of these complex relationships. This understanding will provide the basis for any future regulatory

**An exception to this generalization is the oil-fired boiler which can emit significant amounts of sulfates directly.*

Mechanisms by which Sulfur Dioxide is Converted to Sulfates

Mechanism	*Overall reaction*	*Factors on which sulfate formation primarily depends*
1. Direct photo-oxidation.	$SO_2 \xrightarrow[\text{water}]{\text{light, oxygen}} H_2SO_4$	Sulfur dioxide concentration, sunlight intensity.
2. Indirect photo-oxidation.	$SO_2 \xrightarrow[\text{organic, oxidants, hydroxyl radical (OH)}]{\text{smog, water, } NO_x} H_2SO_4$	Sulfur dioxide concentration, organic oxidant concentration, OH, NO_x.
3. Air oxidation in liquid droplets.	$SO_2 \xrightarrow{\text{liquid water}} H_2SO_3$	Ammonia concentration.
	$NH_3 + H_2SO_3 \xrightarrow{\text{oxygen}} NH_4^+ + SO_4^=$	
4. Catalyzed oxidation in liquid droplets.	$SO_2 \xrightarrow[\text{heavy metal ions}]{\text{oxygen, liquid water}} SO_4^=$	Concentration of heavy metal (Fe, V, Mn) ions.
5. Catalyzed oxidation on dry surfaces.	$SO_2 \xrightarrow[\text{carbon particulate}]{\text{oxygen, water}} H_2SO_4$	Carbon-particle concentration (surface area).

action to limit or reduce the growth of ambient sulfate levels in the U.S. To date, one argument for atmospheric sulfate reduction favors direct control of SO_2. Another argument favors control of photochemical precursors that may be responsible for the larger portion of SO_2-to-sulfate conversion. Much of the ORD sulfate research in the past year has sought evidence to resolve this argument.

The 1977 ORD research achievements in sulfate atmospheric processes have been balanced between theoretical studies and field investigations. One theoretical study and laboratory measurement found that a reduction in the oxidation rate of SO_2 decreases sulfate production faster than a corresponding reduction in the amount of SO_2 in the air. The study also showed that percentage reductions of the photochemical precursors—hydrocarbons and nitrogen oxides in the air—did not produce a corresponding percentage decrease in the sulfate formed. These results support the argument that favors direct SO_2 sion control as the effective means to control sulfates.

Another theoretical study in 1977 compared the sulfate formation rate in clean air to that in typical urban air. It was found that sulfates formed between 2 to 3 times faster in the urban air. The oxidation rate of SO_2 to sulfates in clean air proceeded at approximately 1.5% per hour. In typical urban air, the oxidation rate was calculated at 4% per hour. Thus, the rate of oxidation, taken in conjunction with the location of the SO_2 source, are key parameters in determining where the sulfates will probably occur.

Sulfates and Visibility

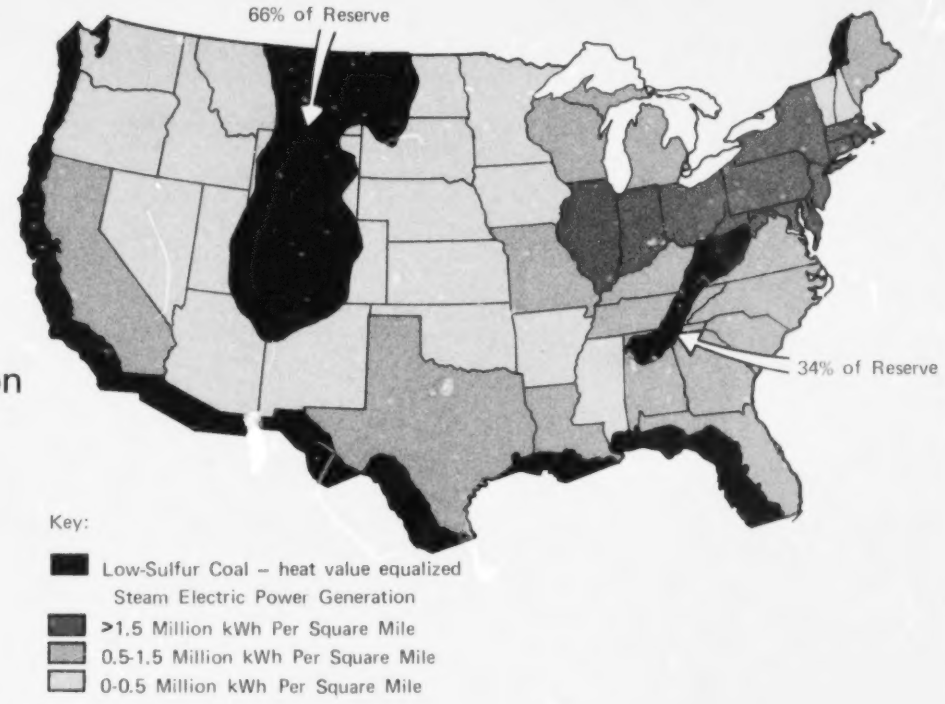
EPA field investigations this past year were aimed at determining the location of high sulfate concentrations. In one study of historical data in the southwestern United States, high correlations were established between ambient sulfate measurements and various indices of visibility.

In another study, a series of sampling programs was conducted in urban areas including New York City; Philadelphia; Charleston, South Carolina; St. Louis; Glendora, California; and Portland, Oregon. Dichotomous samplers, which EPA has been developing over the past five years, were used to collect the sulfate particles. Analyses of the samples revealed that about 70% of the sulfur occurs as fine particles, of which sulfate typically accounts for about 40% of the mass. Detailed sample analyses indicated that sulfates contributed significantly to the acidity of the particulate samples. Specifically, it was found that hydrogen ions (used as an index of acidity) accounted for between 5 and 46% of the cations associated with sulfate.

As further data is produced by this research, a greater understanding of the dynamics of sulfate pollution will evolve. With such an understanding, optimum sulfate control strategies can be developed.

clean energy

ORD attacks sulfates with technology -- coal cleaning, scrubbers and advanced combustion


66% of Reserve
34% of Reserve
Key:
Low-Sulfur Coal – heat value equalized
Steam Electric Power Generation
>1.5 Million kWh Per Square Mile
0.5-1.5 Million kWh Per Square Mile
0-0.5 Million kWh Per Square Mile

President Carter's energy goals call for increased use of coal by industry and utilities in the future. But as more coal is burned, more sulfur could be released to the atmosphere. Its presence could, in turn, create higher sulfate levels in populated areas. The National Energy Plan estimates an increase in annual coal use from its present level of approximately 660-million tons to 1.2-billion tons in 1985.

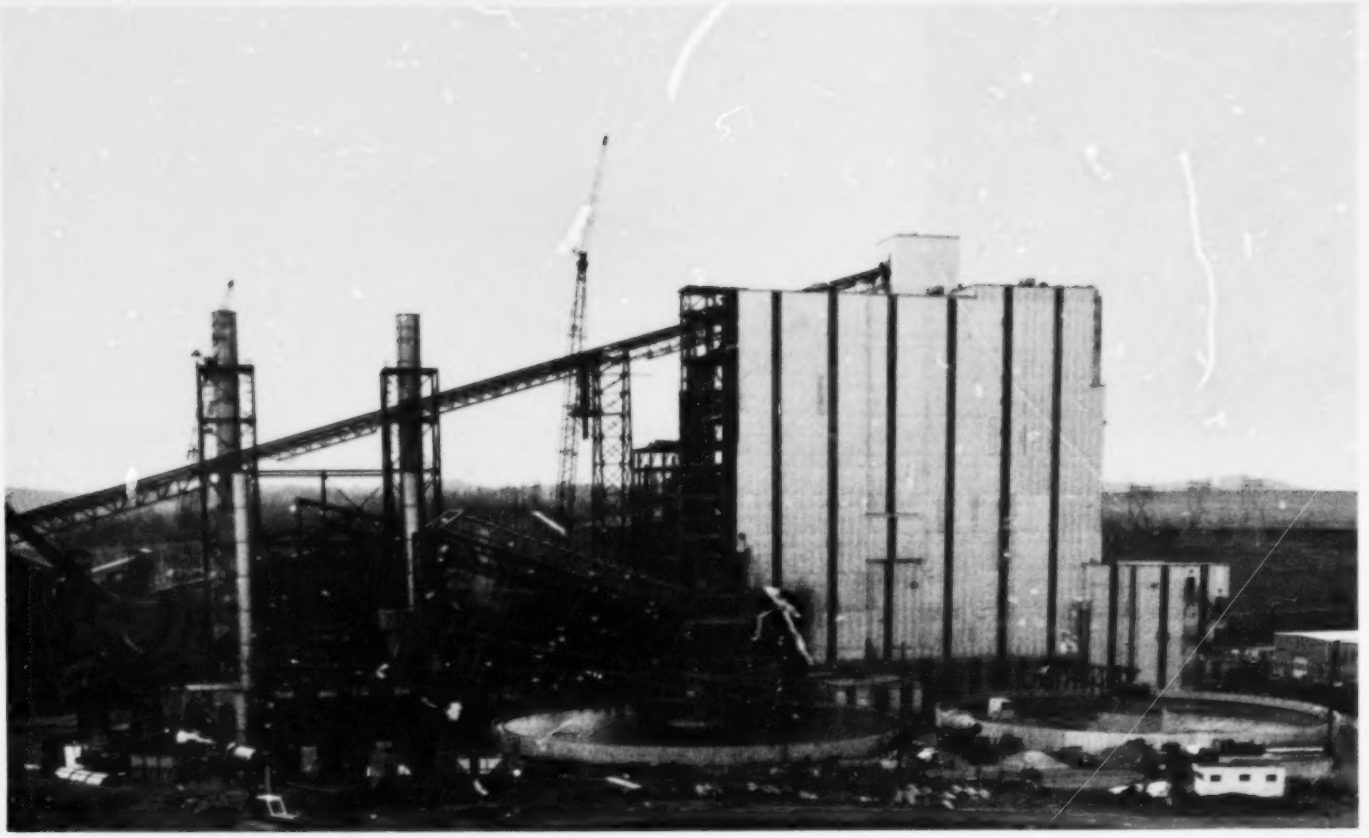
ORD and its predecessor organizations have been instrumental in developing, testing, and assessing alternative sulfur control technologies since the early 1960's. Their research has emphasized the demonstration of technical feasibility to ensure economic acceptance by industry.

There are three basic points at which sulfur pollutants can be removed from the coal power cycle – before combustion (physical or chemical cleaning, synthetic fuels), during combustion (fluidized bed combustion), or from the exhaust gases after combustion (flue gas desulfurization). ORD has had a major, and in some cases the lead, national research role in all of these areas. The ORD role is further augmented by its responsibilities as coordinator of the $100-million per year Interagency Energy/Environment Research and Development program.

Coal Cleaning

Less than 15% of the coal mined in the United States today can meet federal standards governing sulfur oxide emissions from new sources. At EPA during 1977, work has continued on the development of several sulfur removal options for coal. This work includes testing system feasibilities, determining cost figures for industry application, and providing information that can be used by regulating authorities for assessing practical and optimum emission control strategies.

The coal cleaning process is compli-



COAL-CLEANING FOR POWER PLANTS: Nation's first multi-stream physical coal-cleaning facility feeds power-plant complex at Homer City, Pa. ORD is conducting an environmental monitoring study of the facility, which began partial operations in the fall of 1977.

cated by the very nature of coal. Coal is not homogenous. Different seams, or different locations within the same seam or mine, can yield vastly different coal samples in terms of heat value, sulfur, ash and water content. Sulfur itself, within the coals, takes two forms: pyritic sulfur is separable from the coal by physical means (e.g., crushing), organic sulfur is tightly bound to the coal and is difficult to remove.

Locating Cleanable Coal

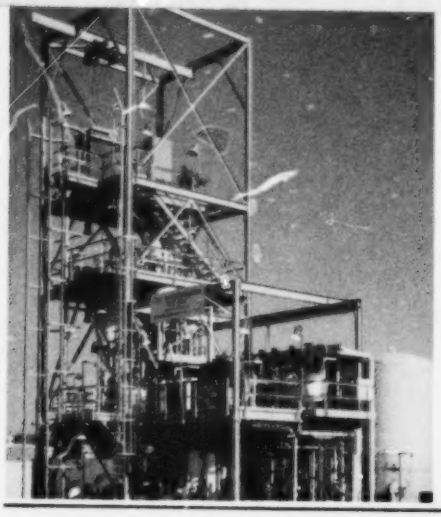
Part of the work of ORD is determining the physical cleanability of various U.S. coals. Under this program, the ultimate cleanability of most major deposits has been determined. This work, which has been performed in conjunction with the U.S. Bureau of Mines, has tested more than 450 samples of coal representing more than 70% of the coal used for U.S. utilities. From these tests ORD and the Bureau of Mines have determined the level of sulfur reduction that can be achieved by physical cleaning as well as the degree of energy loss associated with the cleaning process. There are two basic methods of removing this sulfur: physical coal cleaning and chemical coal cleaning.

Physical Coal Cleaning

Physical coal cleaning involves crushing run-of-mine coal to the point where mineral impurities are released from the coal structure. The process depends upon the difference in physical properties (such as specific gravity or magnetic attraction) between coal and its impurities. In the specific gravity process, the crushed coal is suspended in a dense liquid allowing pyritic sulfur and other mineral particles of higher density than coal to settle out. The remaining coal can then be removed easily from the liquid and burned.

Over the last decade EPA, in conjunction with the Bureau of Mines, the electric utility industry, and private contractors, has conducted R&D on methods of physical coal cleaning. This work has led to the adaptation of a number of physical cleaning methods. Some of these technologies are now being developed for use on a commercial scale in major electric generating plants as a means of achieving compliance with sulfur dioxide emission standards.

Homer City, Pennsylvania, boasts the first of these U.S. coal preparation plants designed to remove sulfur for compliance with state and federal sulfur dioxide emission regulations. The facility, partially funded by ORD, will treat about 1200 tons of coal per hour and will supply all the fuel necessary for an 1850-megawatt power generating system. Two other sulfur removing plants are being planned by TVA.



ORD-sponsored facility tests chemical coal cleaning process.

Chemical Coal Cleaning

Chemical coal cleaning requires run-of-mine coal to be ground to fine granules, after which it is reacted with chemical agents at elevated temperatures and/or pressures to remove impurities and sulfur compounds. Again, this 'cleaning' is performed before combustion.

Several chemical coal cleaning processes are under development. The Meyers Process is the most advanced of these and is currently being evaluated in a 1/3-ton-per-hour pilot plant in Capistrano, California. Funded by ORD, this process has the potential to remove more than 95% of the pyritic sulfur.

At least eight other processes are in various stages of development in bench-scale studies. These processes include microwave desulfurization, hydrotreatment and hydrothermal processes, the latter process claiming 90% removal of pyritic sulfur and 40% removal of organic sulfur. While most of the chemical coal cleaning processes being examined by EPA are capable of removing both organic and pyritic sulfur, the effectiveness of any given process depends on the chemical makeup of the mined coal. Under accelerated development, several chemical processes could be ready for commercial demonstration in 3 to 5 years.

Scrubbers

The most promising sulfur-control technology to date has been a flue gas desulfurization (FGD) 'scrubbing' technique for which nearly $4 billion has been committed by industry. The combined electrical power output represented by this investment is 40,000 megawatts or 10% of this nation's generating capacity.

Research into FGD

FGD systems can either be throwaway systems which require that the by-product sludge be discarded, or regenerable systems that produce a by-product with some use. The FGD systems now in the greatest use are the lime and limestone sludge-producing systems. In these systems, the sludge comes from a lime or limestone that precipitates SO_2 into a calcium sulfate or calcium sulfite salt. ORD, in conjunction with TVA, is operating and testing such systems at the Shawnee Power Plant near Paducah, Kentucky. Continuing tests at this facility are resulting in advances in system reliability, variable load operation, control, sludge disposal, and cost reduction. ORD is sponsoring other large demonstration projects for a number of FGD techniques to adapt these techniques to existing and future power plants of around 100 megawatts capacity, or significantly smaller than most modern utility systems. This would bring scrubbing technologies to industrial-sized applications.

ORD is also considering an applications-oriented program, involving participation by the Electric Power Research Institute (EPRI), the utility industry, and FGD system vendors, to improve the acceptance and application of pilot plant and prototype results to commercial units.

The year 1977 saw the initiation of a major test of what may become the next generation scrubber system. Ground was broken at a site near Louisville, Kentucky, to test the double alkali scrubbing process on a 270-megawatt electric plant burning high-sulfur coal. Cost-shared with the local utility, this ORD demonstration will produce a high quality sludge useful for landfill. Earlier pilot plant tests using the double alkali scrubbing process have indicated improved reliability, significantly improved energy efficiency, and potentially lower capital and operating costs than other scrubbing systems. The Louisville demonstration will determine if, as it appears now, the double alkali process becomes the logical successor to current generation lime/limestone scrubbers.

ORD also has sludge reduction research under way, including disposal techniques and the possible beneficial uses of sludge. Some of the research taking place involves using sludge as fertilizer, or in chemical production plants, and evaluating the likelihood of market penetration.

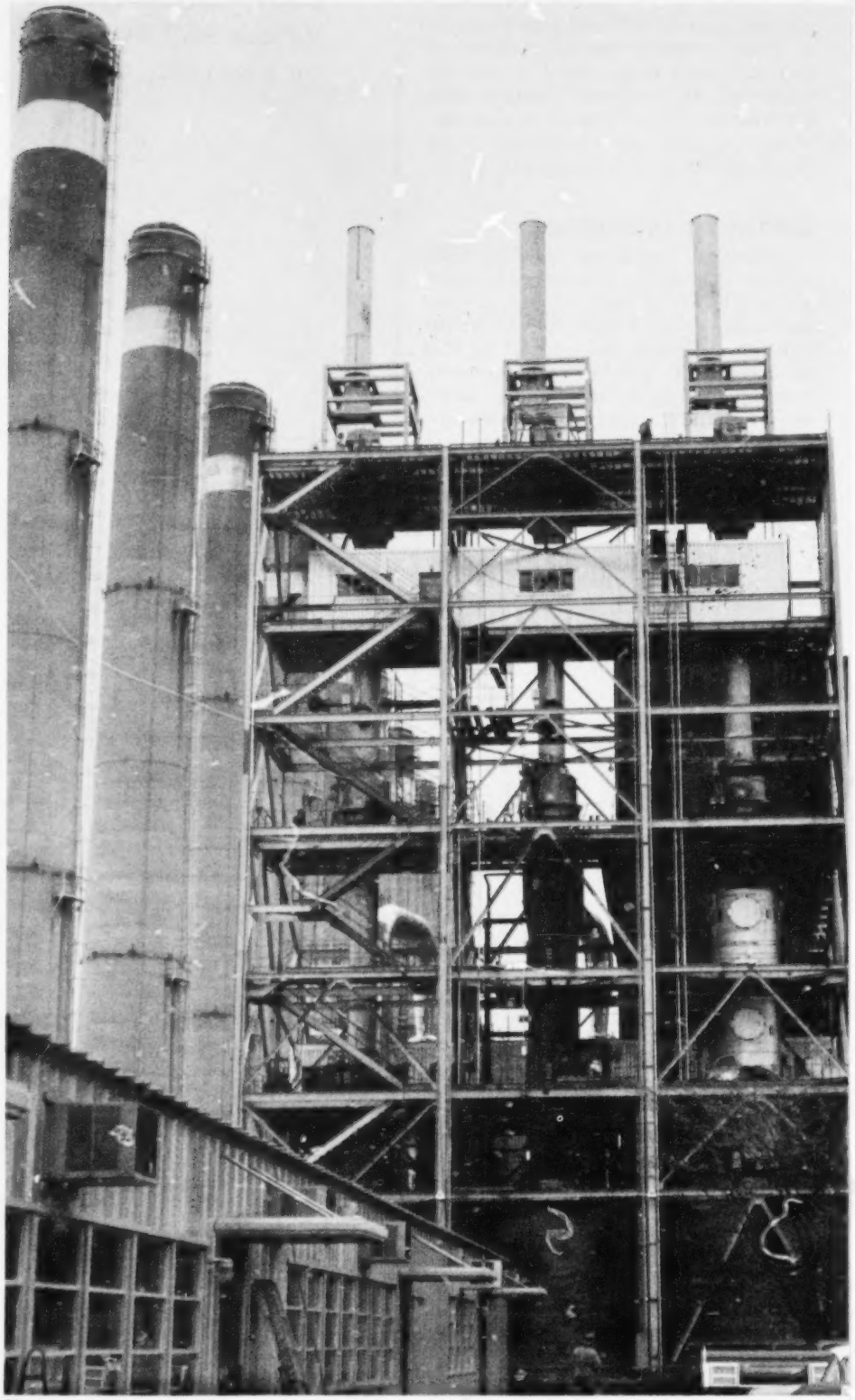
Several FGD systems which do not produce sludge have also been investigated by ORD. Such systems reduce solid waste by regenerating their sorbent and producing a marketable by-product, such as elemental sulfur or sulfuric acid. (Hence the term "regenerable," applied to those scrubbers which produce no waste sludge.)

A major breakthrough in regenerable scrubbing occurred in 1977. In a demonstration cost-shared by ORD and a utility company, the Wellman-Lord sulfur-producing processes was proven effective. The process underwent acceptance testing in 1977 on a 115-megawatt power plant burning high-sulfur midwestern coal near Gary, Indiana. These exhaustive tests of the Wellman-Lord process indicate high reliability and lower operating costs than initially projected. The system produces purified sulfur, instead of sludge, as a by-product. This sulfur is being sold to a commercial firm — thus further reducing system operating costs.

Fluid Bed Systems

The third method of reducing SO_2 emissions from fossil fuel combustion is fluidized bed combustion (FBC). This technology involves the combustion of pulverized coal or 'dirty' residual oil in a bed of limestone that has been fluidized (held in suspension by the controlled injection of air through the bottom of the bed). During combustion, the SO_2 released reacts with the limestone to form a dry solid waste along with the coal ash. This waste thus removes much of the pollution before it enters the exhaust gas. High heat transfers, low sulfur and nitrogen oxide emissions, and responsiveness to varying loads and composition are just a few of the FBC's advantages. ORD anticipates relatively early commercial availability of this process. In 1977, EPA work on FBC has continued on technical applications, emissions control, environmental impact, projected cost comparisons with other sulfur control technologies, and applications to electric utility and large industrial boilers. The process offers the potential of solving the problem of clean energy for medium-scale operations, but it is currently not commercially available for the large boilers required by electric power plants and heavy industry. Although fluidized bed combustion is not a cleaning process per se, it serves a similar environmental function and is, therefore, of interest to ORD.

Other promising technologies involve the creation of low-sulfur synthetic liquid or gaseous fuels from coal. These technologies, under development by the Department of Energy (DOE), are being reviewed in a cooperative ORD/DOE environmental monitoring program. Such synthetic fuels technologies, however, are not expected to make a significant contribution to the nation's energy supply for several years.



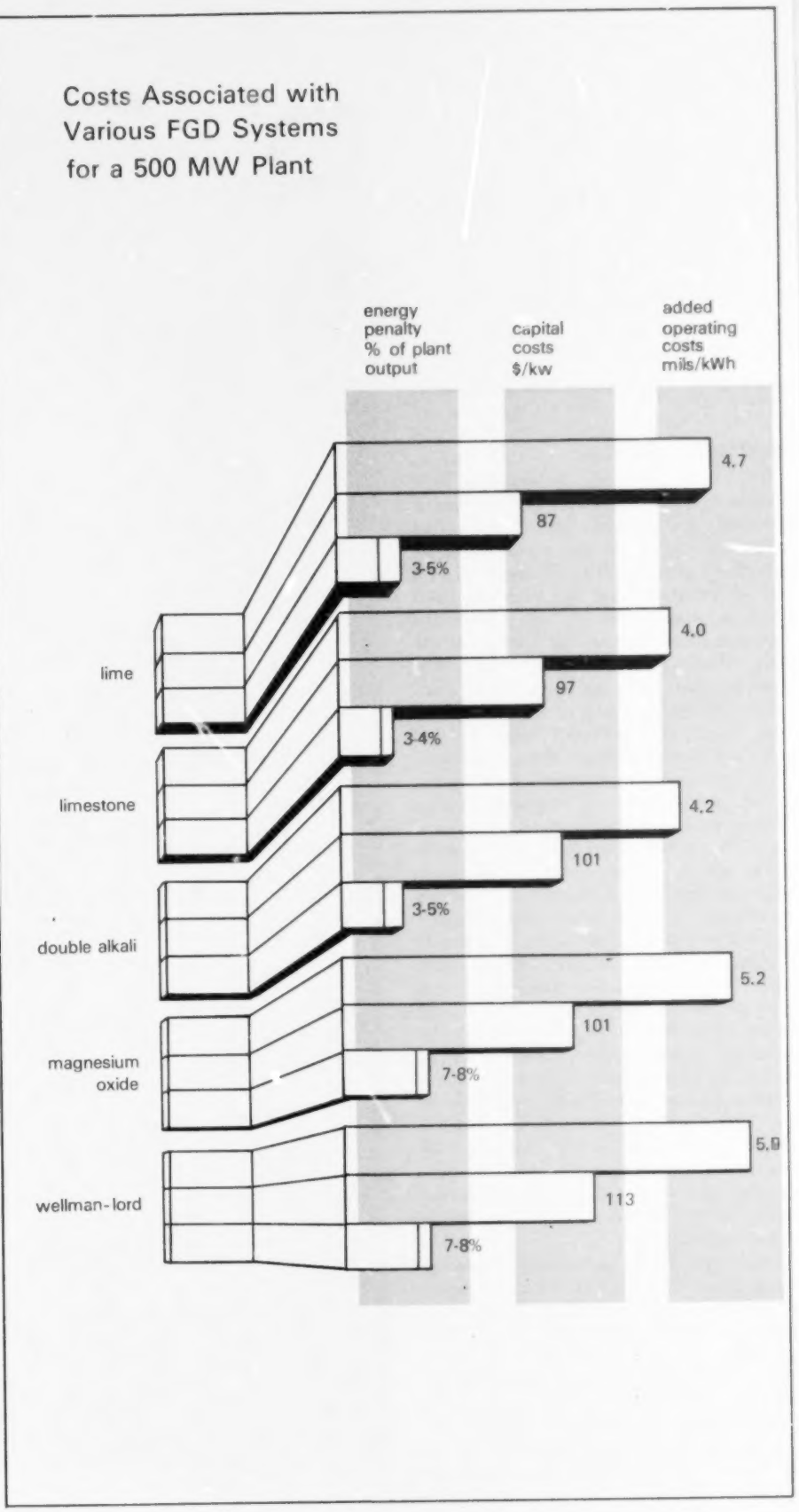
Versatile ORD–sponsored wet scrubber test facility at TVA's Shawnee power plant.

These control technologies are essential for establishing alternative strategies to meet the sulfate hazards of the future. The focus of the control technology research in both 1977 and future years is to make technical options available to coal users as well as control options for regulation. The research is paying close attention to costs of control, to a phasing of controls into new plants, and to the retrofit problems of existing plants.

Combining Technologies

Additional studies performed by ORD indicate that, in many instances, a combination of two or more of coal cleaning and sulfur removal methods can be the most cost effective and efficient method of meeting a specified SO_2 emission standard. Among the determining factors are the emission standards to be met, the location of the plant, the type and makeup of coal, the available water and other necessary resources, the location of end users, and the technical feasibility and costs of the methods.

Continued R&D on all feasible sulfur removal options is essential as the need for energy increases, and as more and better use must be made of the U.S. resources of high-sulfur coals.



The following ORD components contributed to the sulfates research described above:

OFFICE OF ENERGY, MINERALS AND INDUSTRY: • Industrial Environmental Research Laboratory, Research Triangle Park, NC

OFFICE OF HEALTH AND ECOLOGICAL EFFECTS: • Health Effects Research Laboratory, Cincinnati, OH • Health Effects Research Laboratory, Research Triangle Park, NC • Environmental Research Laboratory, Corvallis, OR

OFFICE OF AIR, LAND AND WATER USE: • Environmental Sciences Research Laboratory, Research Triangle Park, NC

OFFICE OF MONITORING AND TECHNICAL SUPPORT: • Environmental Monitoring and Support Laboratory, Las Vegas, NV • Environmental Monitoring and Support Laboratory, Research Triangle Park, NC

cost of power

Economic study provides support to the nation's regulatory and energy-environment decision makers

Several options are available to America's electric utility industry for developing an adequate supply of electricity for the nation's power consumers. But as the demand for electricity grows and the utility industry puts one or more of these options into practice, our economy and environment will be impacted. The extent of those impacts, their nature, location, and their ultimate effect on people are factors which should be known to support the establishment of insightful federal regulatory policies. Until recently, information needed to analyze the effects of various energy "futures" on the economy and environment had not been sufficiently developed to be directly useful to those involved in making major energy and environmental decisions. In addition, no accepted method for such analysis had been established. In recognition of this need, ORD funded a study to provide a scientific method that could be used to answer some of the difficult economic and environmental questions about these futures.

The study is also making a real contribution to a sound basis for evaluating the consequences of federal regulatory policies dealing with future energy development patterns. In addition, the study, which is entitled "An Integrated Technology Assessment of Electric Utility Energy Systems," will help to determine how industry investment decisions are influenced by regional air quality and federal policy. In 1977, the basic method for the study's analytical approach was established, and some initial results are now available.

The Method

The study method combines possible energy and environmental policies with a set of reasonably likely future economic conditions. The synergistic nature of these factors, coupled with legal decisions, new technology research and development, and a description of pertinent climatological effects, are integrated to calculate the rates at which harmful air pollutants will be released in the process of electricity generation. To provide information for regulatory functions, ORD has directed that the study be precise enough to forecast pollution on a county-by-county basis from now through the year 2000. The study methods can, therefore, be used to calculate when and where air pollution patterns will concentrate as the country's energy future takes shape.

The economic portion of the study considers the costs of pollution control strategies to the electric utilities and to electric power consumers. Generally, from the utility's point of view, the technology that requires the lowest capital costs and operational costs to meet air pollution standards is the best. From the consumer's point of view, however, the strategy that causes the least amount of noticeable or hazardous air pollution and that at the same time raises electricity bills the least is the best. The resolution of these differing viewpoints is fundamental to the formulation of a reasonable economic price to pay for clean air. The study method also looks at the economic consequences of alternative environmental policies and their effects on regional coal supply and demand.

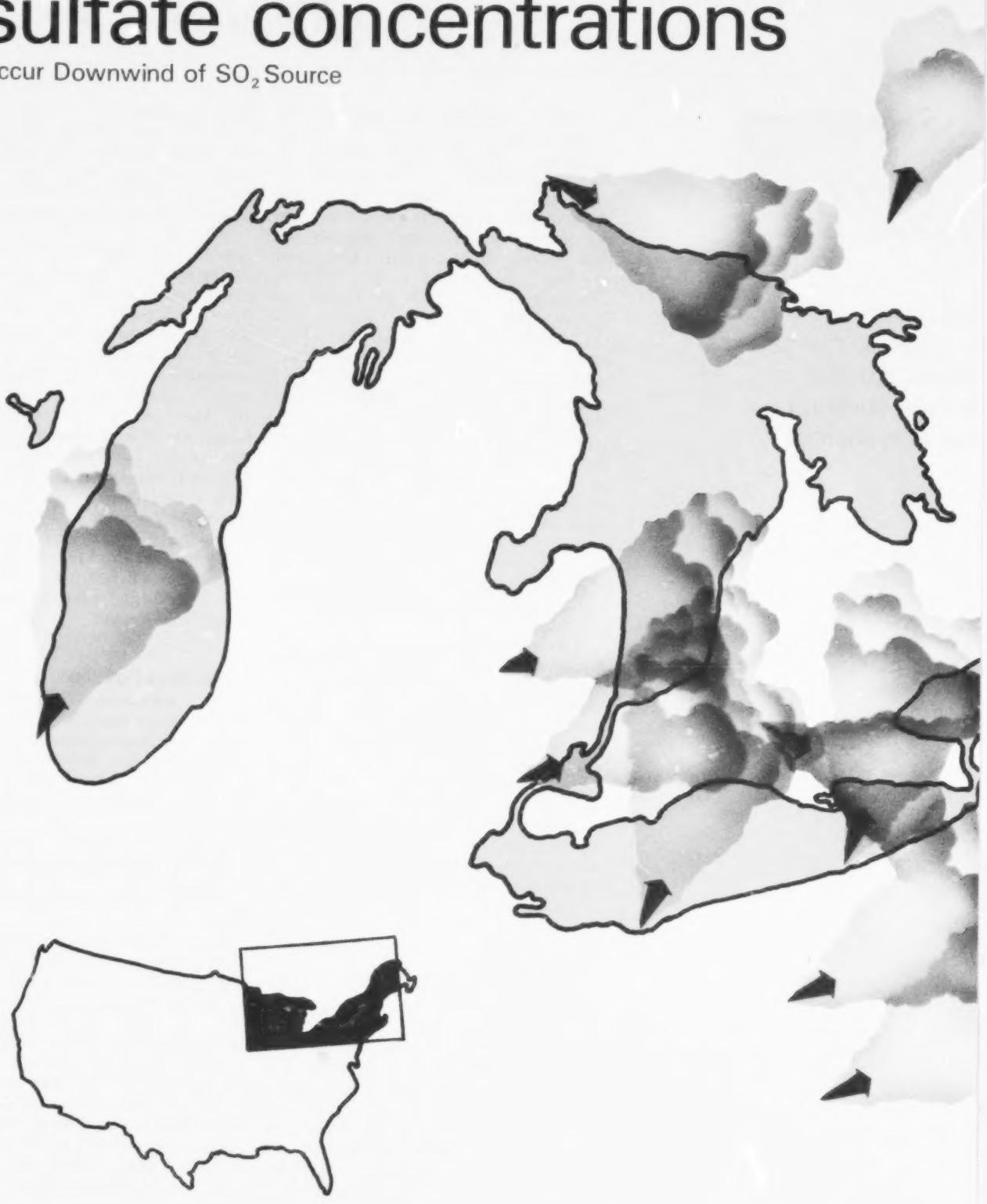
Projecting Pollution

The environmental processes considered in the study take current emission rates from power plants and, through the use of complex meteorological models, project where sulfates will be deposited. Deposit locations and concentrations thus depend on the number of emitting sources, the emissions allowable under applicable air quality standards, the transformation rates of the pollutants, and the prevailing winds that disperse the pollution.

Applying the study method to national sulfur dioxide (SO_2) and sulfate concentrations has uncovered a number of "hot spots" in the country. Not surprisingly, these hot spots have: (1) lenient state implementation plans (SIPs) for air quality, (2) numerous coal-fired power plants, and (3) weather that generally favors pollutant concentrations. For most foreseeable energy futures, these areas will remain problems unless SIPs are modified. However, local efforts may not sufficiently alleviate the problem because sulfates are a long-range interstate phenomenon. One study result indicates that

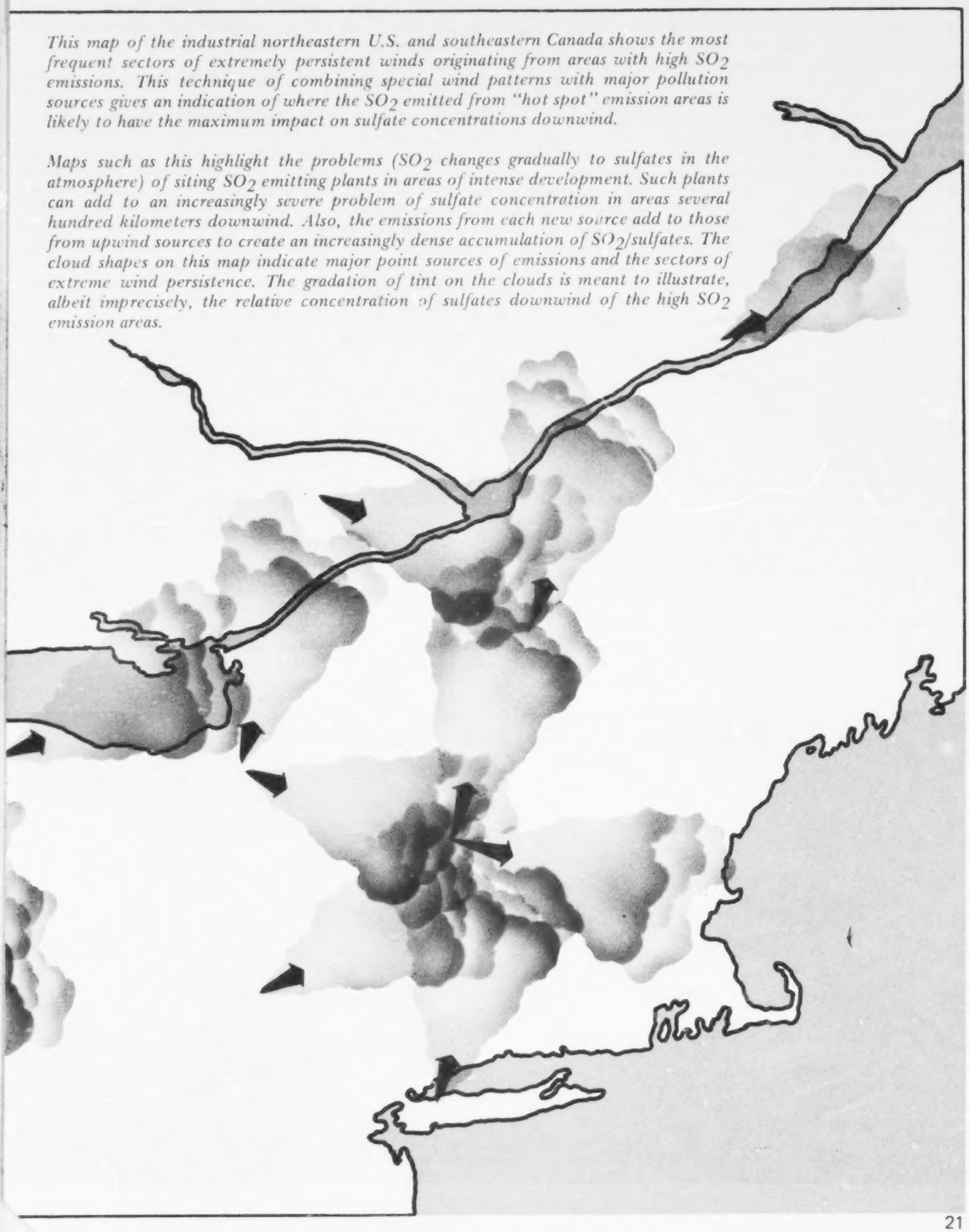
sulfate concentrations

Occur Downwind of SO_2 Source



This map of the industrial northeastern U.S. and southeastern Canada shows the most frequent sectors of extremely persistent winds originating from areas with high SO_2 emissions. This technique of combining special wind patterns with major pollution sources gives an indication of where the SO_2 emitted from "hot spot" emission areas is likely to have the maximum impact on sulfate concentrations downwind.

Maps such as this highlight the problems (SO_2 changes gradually to sulfates in the atmosphere) of siting SO_2 emitting plants in areas of intense development. Such plants can add to an increasingly severe problem of sulfate concentration in areas several hundred kilometers downwind. Also, the emissions from each new source add to those from upwind sources to create an increasingly dense accumulation of SO_2/sulfates. The cloud shapes on this map indicate major point sources of emissions and the sectors of extreme wind persistence. The gradation of tint on the clouds is meant to illustrate, albeit imprecisely, the relative concentration of sulfates downwind of the high SO_2 emission areas.



strict controls on SO_2 emissions from existing power plants can be achieved at reasonable cost if physical coal cleaning is widely used to remove pyritic sulfur. This strategy is valuable to potential investment decision makers because it does not require extensive and expensive plant retrofits. If the practice is widespread, it also means that regional coals having a higher precleaning sulfur content can be used, with attendant lower transportation costs and less environmental disruption.

Another study result illustrates the complex trade-offs involved in energy production and environmental regulation. In the case of SO_2 emissions, a significant rise in this pollutant will occur by 1990 unless strict controls are implemented for *new* power plants. If demand-management policies (e.g., time-of-day pricing) are adopted and are successful in flattening load peaks, the increase in SO_2 emissions will be even greater, necessitating strict controls not only for new but also for *existing* power plants. This apparent inconsistency between managing the load yet increasing SO_2 emissions is caused by the fact that, as load management reduces peaks, newer power plants need not be built. As a result, the older plants will be kept operating more of the time, and the resulting pollution output will be greater than if the new "cleaner" and more efficient plants were built. In addition, peak load flattening may not substantially reduce growth in total demand for electricity. Hence, *total* emissions would increase.

The 1977 results have also allowed EPA to address the questions of: Where will emissions from the "hot-spot" areas be transported? Where will they have their maximum impact in causing high sulfate levels in the atmosphere? The answers are derived by identifying those meteorological conditions which, along with the spatial distribution of emission sources, determine the movement of emissions and the relationships between emissions sources and receptors. These meteorological conditions include the directions of persistent surface winds, the directions of winds at the height of tall power-plant stacks, the paths of power-plant plumes, and the tracks of high-pressure air masses.

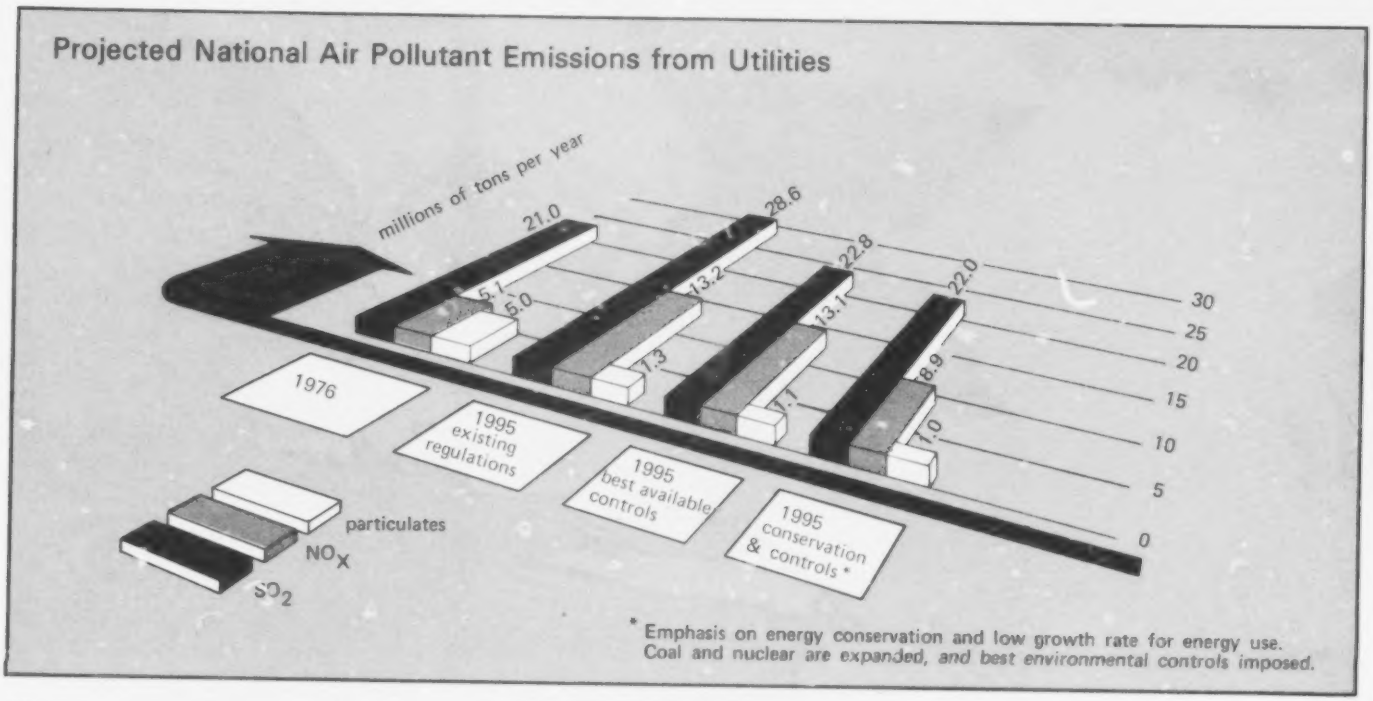
Applying this analytical method to sulfate problem areas, ORD has found that:

- Rural locations likely to have high sulfate levels as a result of power-plant emissions are to the north of the lower Ohio River Basin and to the northeast of the upper Ohio River Basin.

- Numerous areas in the upper and lower Ohio River Basin will contain sites for additional power plants and other emission sources that lie directly along the meteorological paths of medium-range and long-range transport—a condition that will exacerbate the already serious sulfate problem in the Northeast. The region's air resources may not be able to support anticipated energy and industrial developments without implementation, on a regional basis, of stricter controls for existing power plants and siting restrictions for all new sources.

- Much of the long-range transport impacts of emissions from the Ohio River Basin and Appalachian regions will be felt in the area of the Great Lakes and Canada, which itself will probably have high emissions (in northern Illinois, southern Wisconsin, central Michigan, northeastern Ohio, and areas yet to be determined in Canada). The adverse impacts from the long-range transport of emissions across international boundaries may force the adoption of stricter regional controls for existing sources and stricter siting restrictions for all new sources.

The results of this significant study show basically that when coal is the predominant fuel, sulfates will be a problem. In addition, when coal use is encouraged without strict environmental controls, a sulfate problem, often far removed from the source, will result. Investment decisions for control strategies can draw on the results of this study, and the regulatory impacts on those decisions can be analyzed with the study methodology. As results from this study are developed and validated, key energy/environment decision makers, both within the several EPA offices and throughout the federal establishment, are briefed. Such briefings bring the most recent policy-level information directly to those who are influencing the development of national policy.



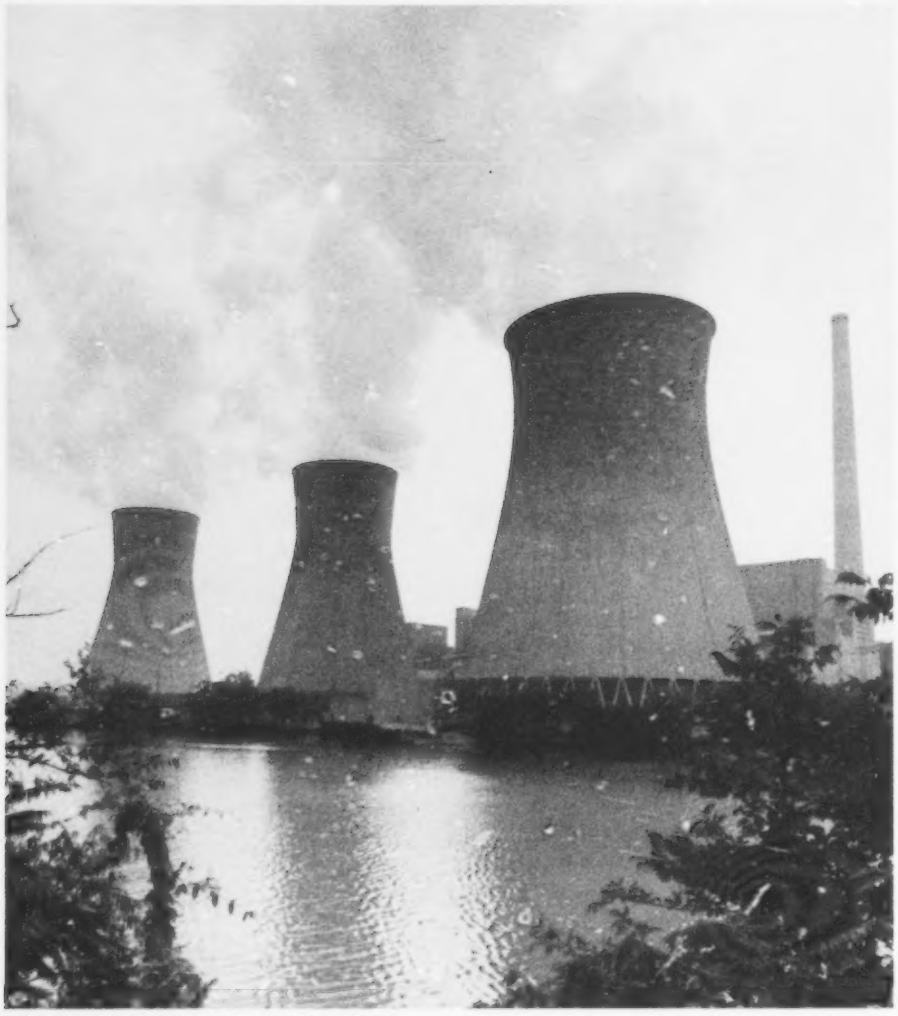
ohio river

ORD leads effort to promote balanced energy development in the Ohio River Basin

The Ohio River Basin Energy Study (ORBES) came about through the efforts of a group of citizens who, in the early 1970's, became concerned about plans for accelerated power plant development along the Ohio River between Portsmouth, Ohio, and Louisville, Kentucky. Currently, nine power plants are under construction or in active planning stages along the 250-mile stretch.

In 1975, at the urging of this group, the U.S. Congress instructed EPA to develop an environmental assessment program. EPA was also given the responsibility of determining social and economic impacts on the area from such development, as well as evaluating whether or not the area required as extensive an energy development program as planned. ORBES is the outgrowth of this Congressional mandate.

Power plant on the Ohio River



COURTESY CINCINNATI GAS & ELECTRIC CO.

Although such environmental impact assessments are not out of the ordinary for EPA research, that this study directly resulted from public concern is. Congress is the client and the public's need for accurate responses to their questions and concerns had to be satisfied. This project serves as an example of direct federal research response to expressed citizen needs.

The first phase of the project, under ORD's management, began in summer 1976, and lasted to fall 1977. In this phase, issues were raised and questions and problems related to an accelerated rate of development in the Ohio River Basin were broadly defined.

Three parallel, but independent, interdisciplinary teams were created, comprising research faculty members from universities in the area. Academic personnel were chosen because of their relative independence from outside interest group pressures, although all interest groups were expected to share the research findings.

ORD first charged the teams with the task of developing four comprehensive scenarios that reflected different potential energy needs and methods for satisfying those needs. The scenarios suggested combinations of electricity generation sources to meet future electrical energy demand growth rates of from 2.8% to 5.8% per year. Plausible sites, based on locational and engineering criteria, were selected for each of the four scenarios for plants operational in specific years between 1975 and 2000.

The second task of this first phase, completed in 1977, was to assess each of the four scenarios. A summary report was then prepared for Congress along with 10 special studies detailing areas of interest that had not been adequately covered in the earlier studies. Study findings indicated that the principal problem with accelerated development in the Ohio River Basin would be air quality degrada-

tion. The siting considerations for the four scenarios showed that most power plants in the region would be located along the Ohio River and its principal tributaries. Under prevailing wind conditions, the preferred power plant sites would be co-directional with the movements of air masses. Emissions from these plants would thus combine with previously emitted upwind power plant emissions to produce an escalating effect on ambient pollutant concentrations. These results, coupled with the work described in the previous section, indicate that severe regional air quality problems would result.

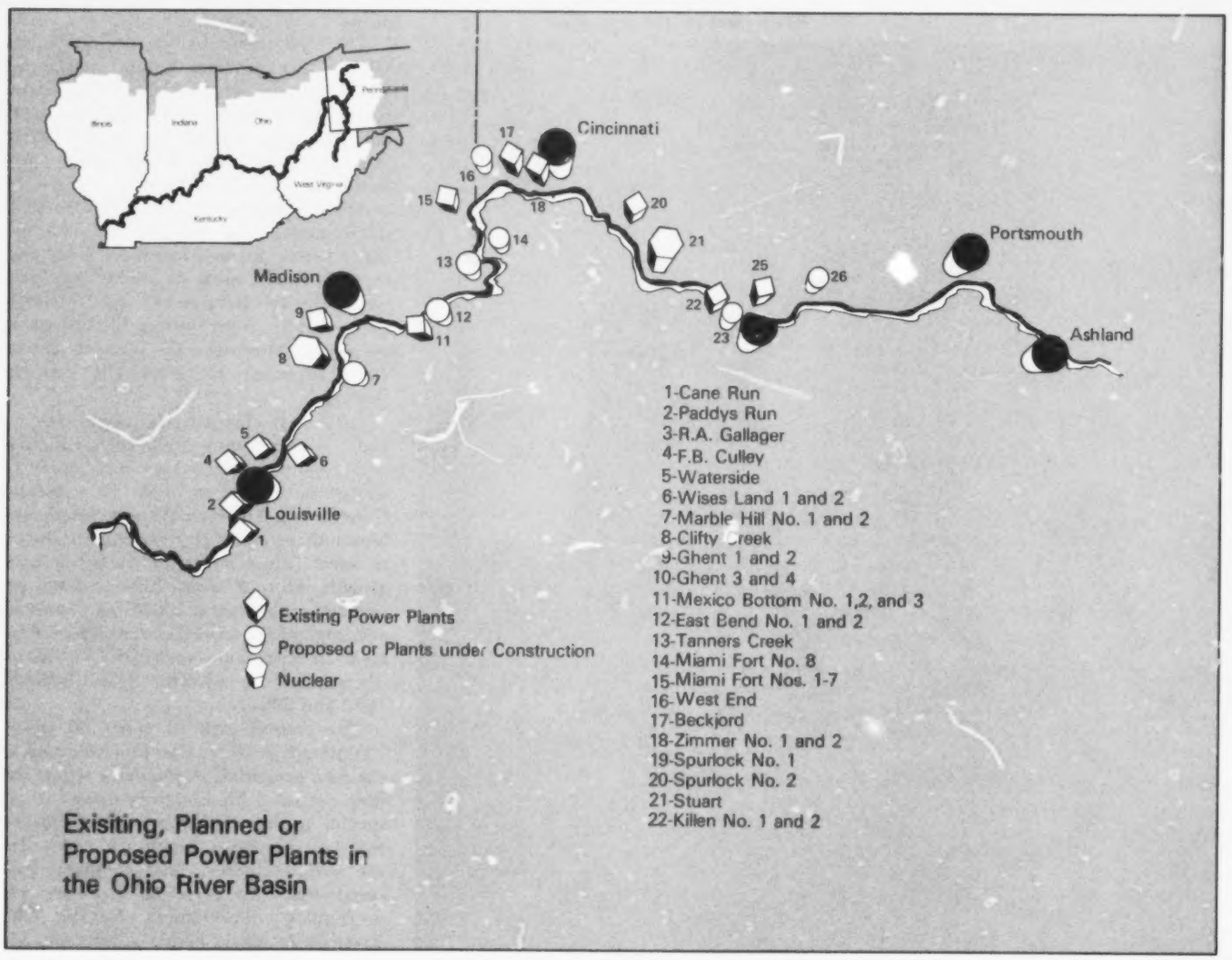
Other potential problem areas include water availability and coal mining. Exploitation of both resources for energy production could degrade land quality and productivity for local areas, or produce other land-use conflicts, particularly with agriculture. Certain coal-mining activities, if uncontrolled, could create water quality problems for decades to come. Rapid expansion of power plant constructionn activities could al unfavorably affect communities remote from experienced labor pools.

These problems can all be significantly reduced or even eliminated. However, most of the solutions appear to depend on a level of regional coordination that does not currently exist. Of the planning, review, and control authorities now operating in the region, none possesses sufficient authority or controls adequate resources to ensure that the public's good will be served and protected; nor does any have sufficient power to coordinate the activities of other agencies.

For this reason, ORD has undertaken ORBES Phase II to investigate possible institutional solutions for guiding regional energy development. The public's involvement, that both spurred the initial project and was an integral part of the first phase, continues and will be expanded in the second phase. As a result, ORBES serves as an organizational model for other regional technology assessments and as an example of a cooperative process toward a common end among concerned citizens, labor, industry, academia, and the government.

The following ORD component contributed to the research described above:

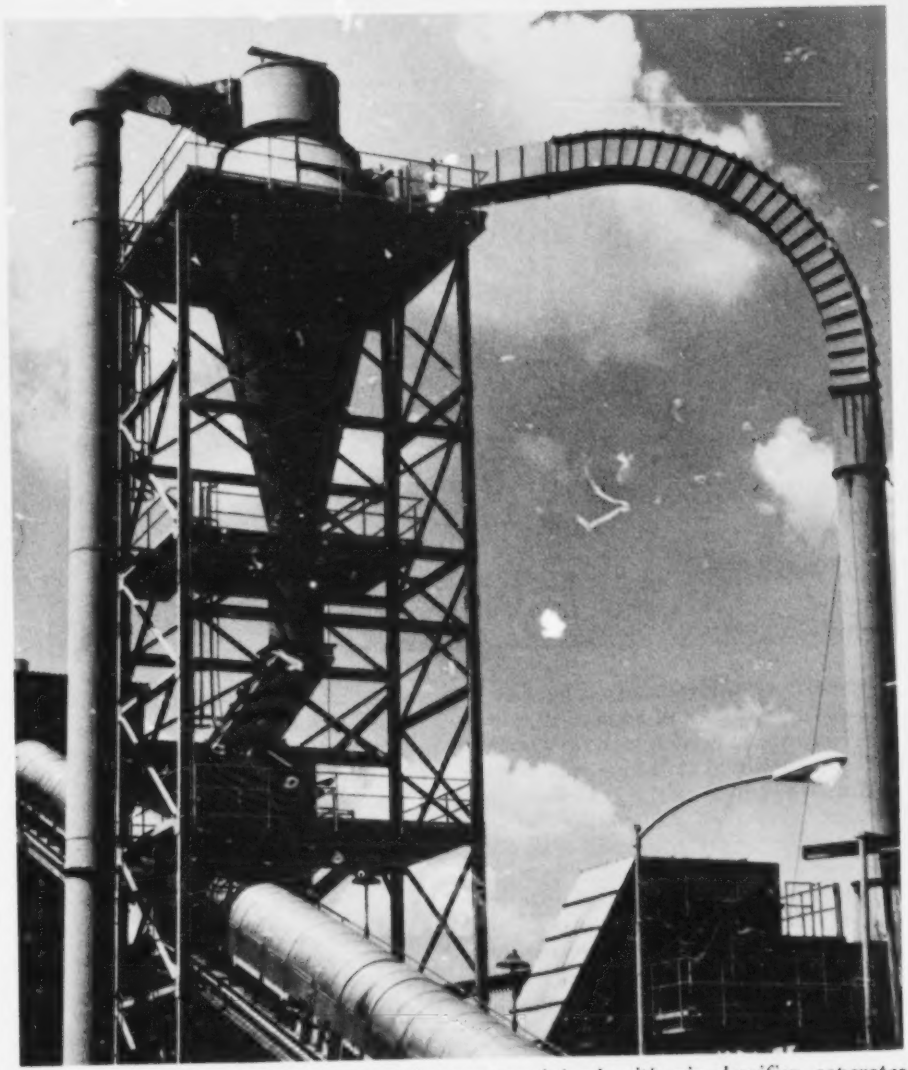
OFFICE OF ENERGY, MINERALS AND INDUSTRY



Exisiting, Planned or Proposed Power Plants in the Ohio River Basin

energy from waste

ORD develops ways to produce energy while disposing of municipal wastes



WASTE SORTING SYSTEM: Inertial separator, joined with air classifier, separates municipal wastes into several streams which may be burned for energy (paper, plastics, etc.) or recycled (glass, metals).

Municipal solid wastes (MSW) present an ever-increasing environmental problem, in the form of air pollution from the uncontrolled burning of these materials, and water pollution from run-off and leaching of wastes dumped in landfills.

Ironically, the MSW discarded in this manner is an untapped source of energy. ORD is interested in the recovery of fuel from waste, and has sponsored a number of projects to demonstrate the feasibility of recovering this energy in a clean and economically practical manner.

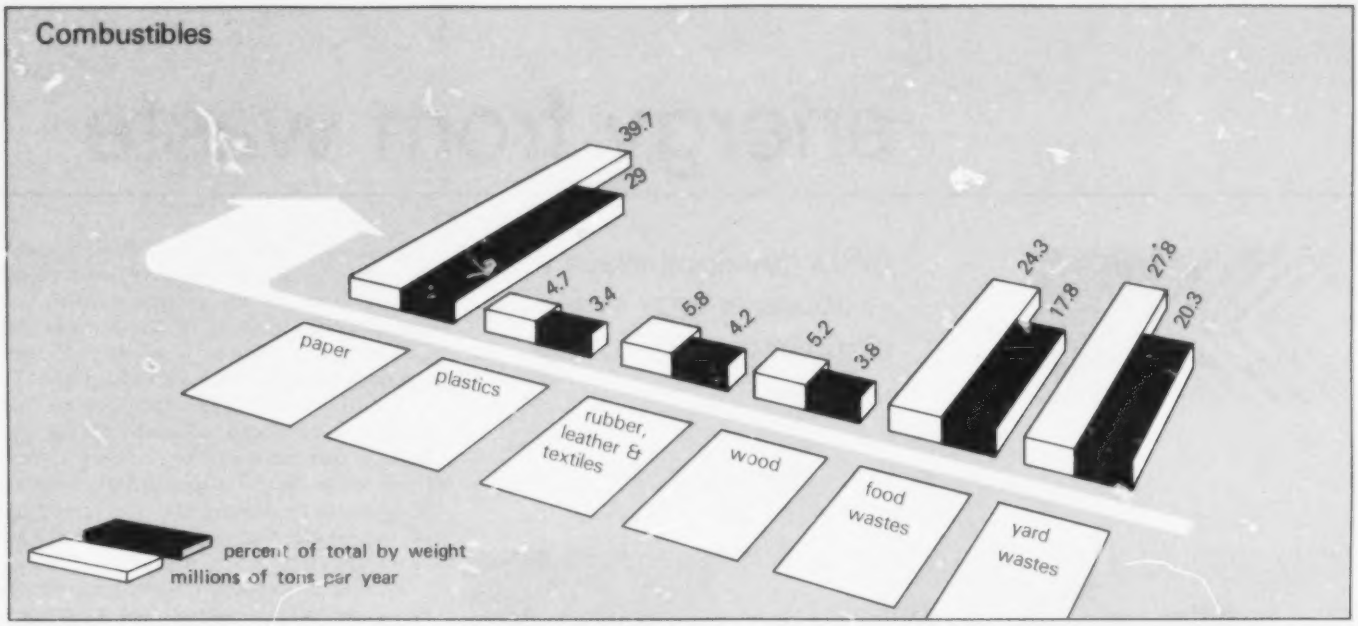
European countries have long recognized the energy potential of MSW, and have incorporated boilers for the recovery of heat into their incineration process. In the United States, recovering the energy potential of MSW was not considered practical until the early 1970s. Then, at an EPA project in St. Louis, finely shredded paper and wood (the "lighter fraction" of MSW) were separated from other solid wastes and used to supplement coal in coal-fired boilers.

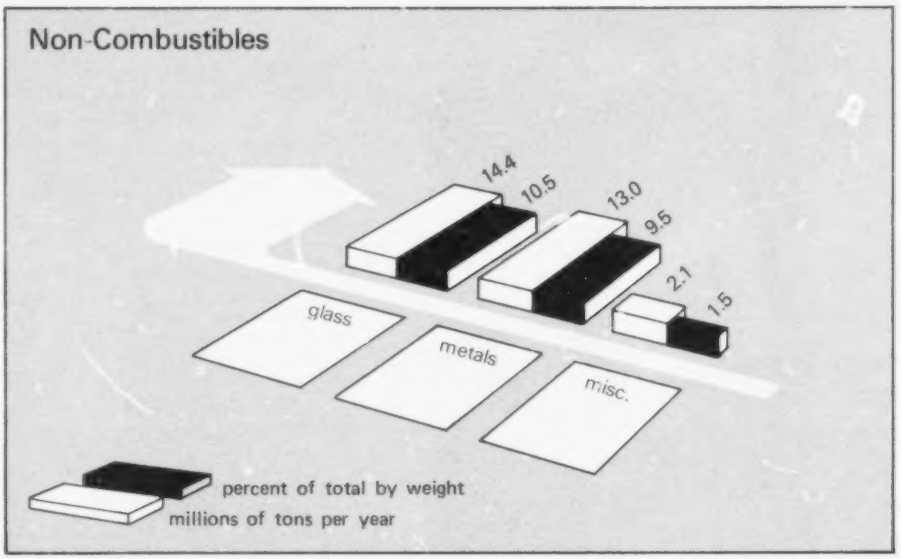
Now, ORD is embarking on a new project to recover energy from municipal solid waste. ORD is sponsoring a pilot project to develop and test "densified Refuse Derived Fuel," or "d-RDF." The source of d-RDF is the lighter fraction of MSW as first separated from solid waste in the St. Louis project.

The Promise of d-RDF

Coal-fired boilers produce a large share of the energy used in the United States. This share may increase in the future. Small boilers generating less than 200,000 lb/hr of steam generate approximately 12% of the electricity in America, and more than half of the roughly 42,000 industrial boilers now in use are coal-fired. As a supplement to coal, d-RDF offers particular advantages, including the following:

- d-RDF may be produced near the user to minimize transportation costs.
- d-RDF is inexpensive to transport.
- d-RDF can be stored for long periods.
- d-RDF can be used by smaller fuel consumers at lower cost than other fuels.
- d-RDF has a low sulfur content.





In addition to its advantages as a source of energy, converting MSW into fuel will help solve the urban waste disposal problem. ORD conservatively estimates that approximately one-third of the urban waste produced in the United States could be effectively used as d-RDF.

The EPA-sponsored pilot plant in Washington, D.C., is preparing d-RDF in a process which can produce 15 to 25 tons of d-RDF per day.

In another phase of the pilot project, compressed pellets of d-RDF are being tested as a coal supplement. This test phase is conducted under contract with the State of Maryland, at a boiler located at the Maryland Correctional Institute in Hagerstown.

In the Hagerstown tests, d-RDF is mixed with coal in varying proportions, and each mixture is burned to evaluate its performance as a fuel. Although there is some decline in efficiency at high loads, at some low loads, the blends of coal and d-RDF seem to perform better and at higher efficiencies than coal burned alone.

d-RDF and Air Pollution

The air emission profile of d-RDF-coal blends appears to be mixed. Particulate and sulfur dioxide emissions drop when d-RDF is burned with coal, but chloride emissions that result from the burning of polyvinyl chloride (PVC) in the waste rise significantly as the proportion of d-RDF is increased in the blend. The oxides of nitrogen, fluourides, and hydrocarbon emitted, however, do not vary appreciably with the blend.

The Hagerstown tests prove that blends of coal and d-RDF can be used to generate electricity in existing coal-fired boilers without significant environmental risk or expensive power plant modifications. Though some loss of boiler efficiency occurs when d-RDF is blended with coal, this economic penalty is offset by major benefits. These benefits include the low cost of d-RDF as a fuel, and the savings to communities achieved through reducing the cost of, and pollution from, conventional municipal solid waste disposal methods.

The d-RDF pilot project will soon be expanded into a well-monitored demonstration of the use of d-RDF in an industrial boiler, where fuel performance can be studied continuously over long periods. This demonstration, if successful, should lead to the widespread commercialization of systems using d-RDF as fuel. The current ORD estimate is that using MSW as d-RDF fuel would produce a nationwide energy savings equivalent to 180 million barrels of oil per year.

The following ORD components contributed to the research described above:

OFFICE OF ENERGY, MINERALS AND INDUSTRY: • Industrial Environmental Research Laboratory, Cincinnati, OH

OFFICE OF AIR, LAND AND WATER USE: • Municipal Environmental Research Laboratory, Cincinnati, OH

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geothermal

ORD plays key role in coordinating the development of preliminary environmental guidelines

Geothermal energy sources are generally assumed to be cleaner and safer than other conventional sources of electricity. This view is not entirely correct. Unresolved technological and environmental problems continue to affect the development of geothermal energy.

In 1977, EPA/ORD was involved in a program to define the environmental hazards associated with geothermal energy and to work toward the establishment of preliminary guidelines for development. It is hoped that these guidelines will encourage environmentally sound development of underground heat resources by providing developers, in advance, with the data they will need to minimize environmental problems before making substantial investments.

Status of Geothermal Energy

Although geysers and hot springs are the best potential sources of geothermal energy in the United States, they constitute only a small portion of the heat energy available for use near the surface of the earth. Other thermal energy resources being explored include hot water systems, igneous systems (molten and hot rock sources), and conduction systems (hot sections of the earth's subsurface). In igneous systems alone, the total heat energy in the United States is estimated to be 30 times the total contained in hot vapor (e.g., geysers) and hot water systems at depths of less than 3 kilometers.

The technology necessary to harness these different types of geothermal resources is still evolving. The one commercial geothermal power complex in the United States is located at The Geysers in Sonoma County, California. The basic means by which The Geysers power plant captures energy is via a "dry steam" system. Operation involves drilling for steam and then piping it to steam-driven turbines which generate electricity.

The technology required for non-vapor sources is more elusive and complex. Hot water systems are being explored in a number of areas in the United States, most notably in the Imperial Valley Basin in California. Methods of extracting energy from hot water systems include flashed steam (capturing steam emitted

when hot water hits the surface air), binary fluid (hot water used to heat a second fluid with a low boiling point such as freon), and total flow (combination of turbine and waterwheel). As mentioned earlier, igneous and conduction sources have tremendous energy potential. However, the technology for their development does not appear to be feasible until the late 1980's.

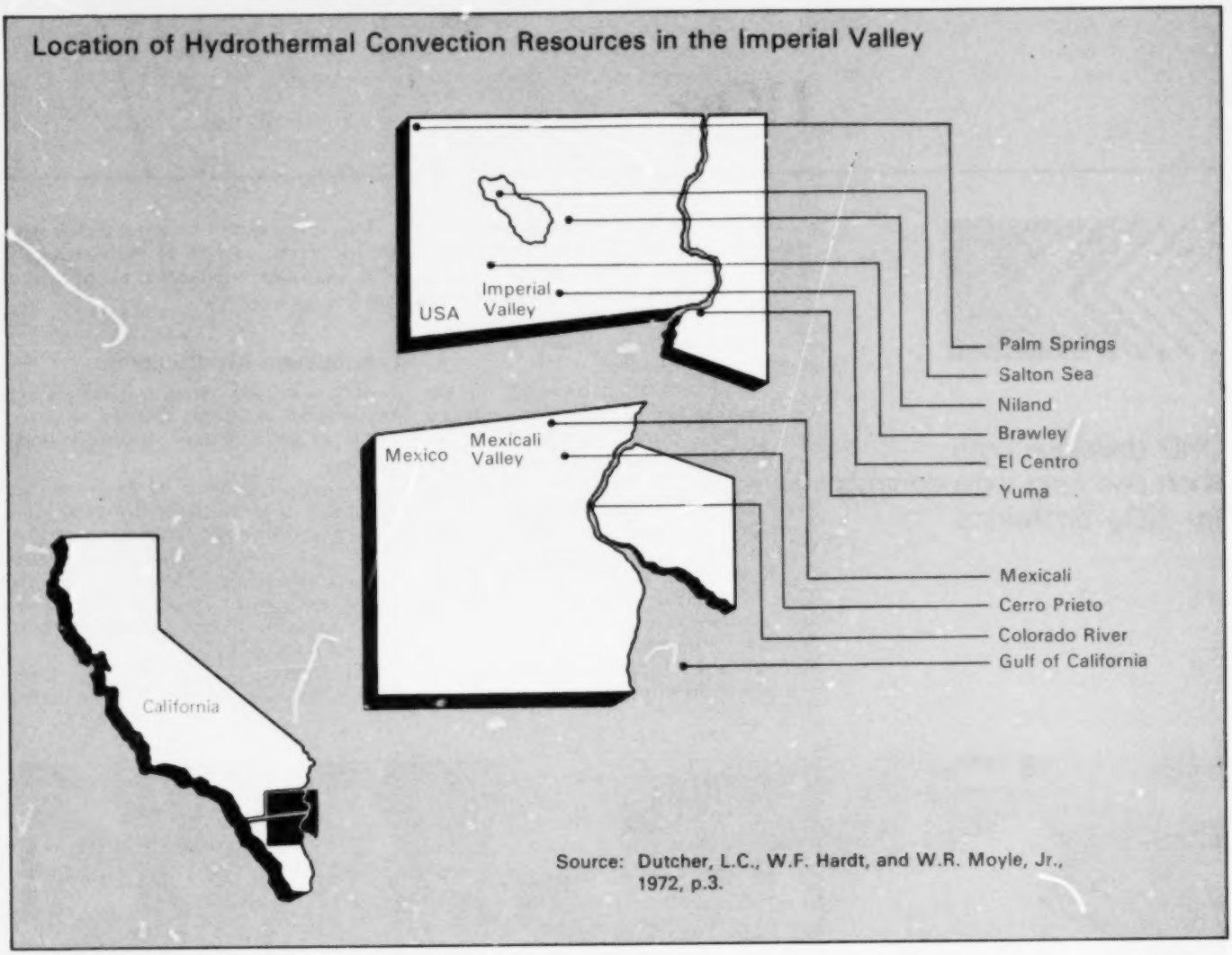
Environmental Concerns

Geothermal sources have considerable environmental benefits, such as low requirements for infrastructure and equipment, relatively minor needs for emissions controls, minimal disruption of the earth, and a high level of safety. However, there remain some significant problems.

ORD, with the Department of Energy (DOE) and other federal agencies, has studied a number of specific environmental problems affecting development and production of geothermal energy. Some of the problems are disruption of land-use patterns, land subsidence and induced seismic activity, some degradation of nearby surface and ground waters, hydrogen sulfide emissions, noise, adverse effects on nearby ecosystems, and localized climate modifications. All of these potential problems are being analyzed to determine their severity and to develop and evaluate control technologies.

Potential Environmental Impacts of Geothermal Power Production

Impact	*Estimate of Probability*	*Technology/ Resource Type*	*Severity of Consequences*
Land subsidence	moderate	hot-water	variable-can be high
Induced seismic activity (earthquakes)	low	all	high
Air pollution resulting from discharge of noncondensable gases (e.g., hydrogen sulfide, carbon dioxide)	high	all except hot-water binary fluid and other "closed-cycle" use of geothermal fluids	variable-depends on emission controls
High noise levels of drilling and plant operation	high	all; worst for vapor-dominated	moderate
Chemical or thermal pollution of surface and groundwaters	moderate	all; greatest probability with hot-water	high
Well blowouts	low	hot-water; vapor-dominated	moderate
Increased erosion and sedimentation resulting from site disturbance	high	all	moderate
Consumption of water for cooling purposes	high	hot-water binary fluid; hot dry rock	high
Consumption of land for wells, power plants, transmission lines	high	all	moderate
Short-term climatic changes resulting from release of heated steam and carbon dioxide	high	hot-water; vapor-dominated	low
Disturbance of habitat; alteration of ecosystems	moderate to high	all	moderate to low



lems are being analyzed to determine their severity and to develop and evaluate control technologies.

ORD'S Role

It is clear that the growing geothermal energy industry will require regulation, in accord with the environmental concerns outlined above. Ultimately, EPA will apply the findings of its research, and the findings of others, to develop regulations to protect the environment from the consequences of unrestricted geothermal development.

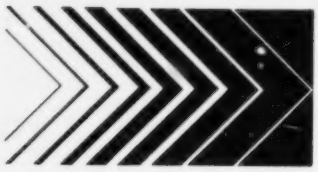
In the last year, the Interagency Geothermal Coordinating Council (IGCC) asked EPA to devise model environmental guidelines for geothermal development, in anticipation of regulations that will eventually be required. In 1977, in partial fulfillment of this request, ORD published a "Geothermal Industry Guidance Manual," the first in a series of publications that will alert developers to environmental constraints. ORD, in its role as the internal EPA coordinator of this guidance manual, assured the involvement with, and concurrence of, every major federal organization concerned about geothermal development.

In an area where so many questions remain unanswered, ORD has tried to facilitate planning by developers that is both consistent with environmental protection and economic realities. The publication series that ORD will issue in concert with the EPA regulatory offices, will describe prototype regulations and will also describe control technologies, the effects of geothermal pollution, and economic considerations. This approach is designed to minimize the disruption to established facilities which could result later when standards with the force and effect of law emerge.

The following ORD component contributed to the research described above:

OFFICE OF ENERGY, MINERALS AND INDUSTRY

NO_X



ORD develops both short and long-term controls for NO_X emissions

The increased use of coal in stationary combustion sources (boilers) may mean a marked increase in oxides of nitrogen (NO_X) emissions over and above present regulatory levels. To alleviate this predicted decline in air quality, new NO_X controls will be needed.

Currently, ORD is working on the development and demonstration of new boiler NO_X control technologies. This research will be increasingly valuable. For instance even at low NO_X levels, data suggest that these emissions are at least partially responsible for damaging the Earth's ozone layer, creating smog, causing high nitrate rainfall, and aggravating various health problems. Additional studies show that exposure to NO_X contributes to the risk of acute respiratory disease and susceptibility to chronic respiratory infection.

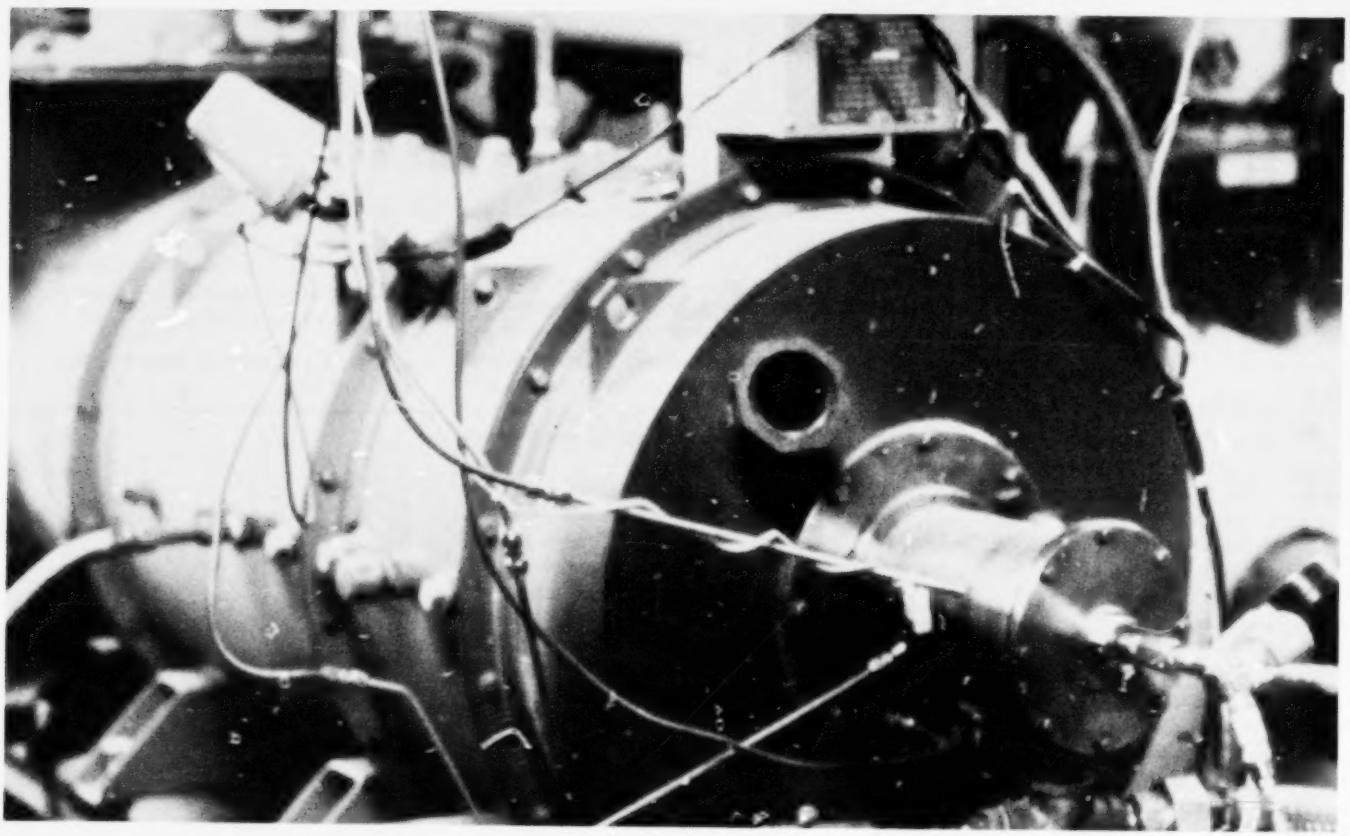
Two major areas of control technology are of interest to EPA in the control of NO_X emissions: combustion modification and flue gas treatment.

Combustion Modification

NO_X is formed during combustion via two distinct reactions: fixation of nitrogen in air and oxidation of nitrogen from the fuel.

Fixation of nitrogen in the air can be controlled by lowering the flame temperature. This flame temperature can be reduced by a variety of combustion modification techniques. Flue gas can be recirculated, water or steam can be injected into the boiler, to limit the heat released from the boiler.

The largest portion of NO_X from boilers, however, is created by the oxida-



Test boiler in which ORD develops NO_X control methods

tion of nitrogen in the fuel. One possible means to limit this reaction is by reducing the oxygen levels within the combustion zone.

In 1977, ORD's research into combustion modification proved it to be both relatively inexpensive and capable of reducing NO_x emissions by 50% or more. However, side effects of this control technology could release other pollutants, increase boiler corrosion rates, decrease boiler efficiency, and create additional particulate emissions. ORD's 1977 accomplishments in combustion modification are a first step toward NO_x control technology to satisfy today's air quality standards.

Flue Gas Treatment

For the future, there are two basic methods of flue gas treatment (FGT) under study by ORD: dry FGT and wet FGT.

Dry FGT is basically a catalytic reduction reaction. During this reaction, the nitrogen oxide gases come into contact with ammonia over catalysts to reduce the nitrogen to water and elemental nitrogen.

Wet FGT is essentially a modification of flue gas desulfurization (FGD), or wet scrubbing, where a portion of the FGD scrubber liquid is used to remove the NO_x.

Both wet and dry FGT for NO_x control are relatively new areas of research in the United States. Japan, however, has been using both technologies on gas- and oil-fired boilers for a number of years. In Japan, dry technology on boilers for electricity generation was found to be more effective with a capital cost of around $25 to $50 per kW and operating costs of approximately 2.0 to 3.3 mils per kWh.

ORD is currently examining, the possibility of applying the dry FGT method to coal-fired boilers and is, at the same time, working to launch a longer term effort for wet FGT. With wet FGT, EPA expects to realize NO_x removal of up to 90%, with capital and operating costs similar to those of flue gas desulfurization.

Advanced Burner Design

An alternative method of NO_x control is the advanced burner design. Such advances promise to reduce NO_x emissions by 85% without reducing boiler efficiency. In 1977, ORD designed and constructed coal burners in the 1.2 to 12 MWe range. Initial data from the six MWe advanced burner test were encouraging—NO_x emissions were reduced by 80% to 85% compared with emissions from standard burners. Further testing is to continue in 1978.

Combustion modification is already a reality for the control of many NO_x emissions. Contemporary legal requirements can be met using this straightforward control technology supported by ORD. In the future, however, combustion modification will not be sufficient to meet the stricter regulations that are expected to be set for NO_x emissions. For this reason, ORD is concentrating on the timely development of adequate flue gas treatment and advanced low-NO_x burners.

The following ORD components contributed to the research described above:

OFFICE OF ENERGY, MINERALS AND INDUSTRY: •Industrial Environmental Research Laboratory, Research Triangle Park, NC

Present and Future (Controlled) NO_2 Emission Levels for Utility Boilers

Generating Input Greater Than 250×10^6 BTU/HR

	Uncontrolled		*New Source Performance Standard*		*Future Target Values*	
Fuel	*LB. $NO_2/10^6$ BTU (2 Hr. Avg)*	*PPM (3% O_2)*	*LB. $NO_2/10^6$ BTU (2 Hr. Avg.)*	*PPM (3% O_2)*	*LB. $NO_2/10^6$ BTU (2 Hr. Avg.)*	*PPM*
Coal	0.42 - 2.10	300-1500	0.7	500	0.21	150
Oil	0.13 - 0.91	100-700	0.3	230	0.13	100
Gas	0.12 - 1.79	100-1500	0.2	168	0.09	75

cleaner cars

ORD's research into pollutants from automobile catalytic mufflers

Within the last ten years catalytic controls have been developed to reduce the emissions of regulated pollutants from vehicles. It has since become apparent, however, that these catalysts themselves produce other pollutants for which no standards have been set. The Catalytic Research Program, created by EPA in 1974, studies these secondary pollutants and their effects on human and animal health. Additionally, roadway air quality is being monitored and research is continuing on new catalytic devices and new automobile engines.

The major benefactor of this research is EPA's own Office of Mobile Source Air Pollution Control which, through use of the data, determines whether new cars are emitting pollutants that might be harmful. Benefits of the research can also accrue to automobile manufacturers, federal, state and local air quality programs, and others involved in automotive pollution control.

Volvo photo

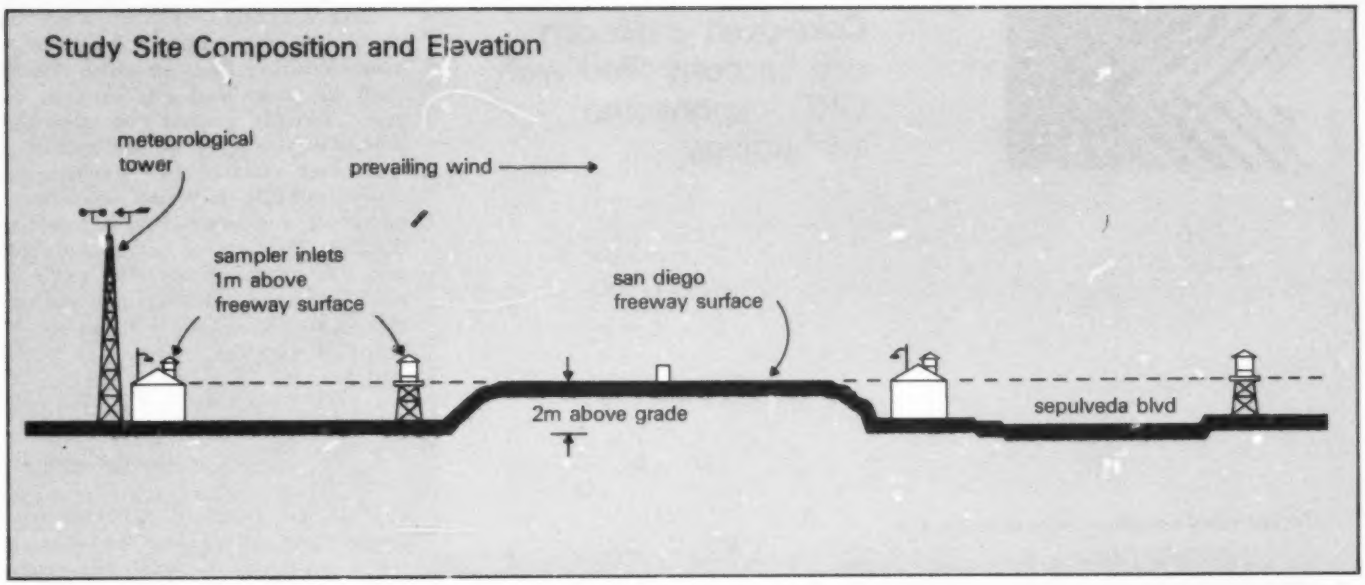
Sulfuric Acid

Concern over heightened sulfuric acid levels caused by catalysts was a major area addressed by ORD's 1977 research efforts. Earlier findings of low sulfuric acid emissions in dynamometer tests were confirmed by current findings. These findings indicate a low concentration level for sulfuric acid or other sulfur species in the roadway. And, preliminary health effects studies on sulfuric acid alone indicate that people might be able to tolerate the levels of sulfuric acid expected to be in ambient air surrounding roadways. However, studies of the synergistic effect of sulfuric acid in combination with other automobile related pollutants have not been completed.

Additional data indicate that when automobiles modify the atmosphere immediately above and close to the road unusual effects occur. One finding indicates that the speed, proximity and location of vehicles moving in a cluster are a more significant determinant of pollution concentration than is the average vehicle emissions over the roadway.

Toxicological tests on sulfuric acid and manganese emission compounds were performed to determine the health effects of these compounds that can be expected at particular pollutant concentrations. Short-term sequential exposure to low concentrations of ozone and sulfuric acid, for example, increased the susceptibility of laboratory animals to pulmonary bacterial infections. (See *Sulfates—health* chapter.)

In 1977 new exposure chambers were built in which test animals can be exposed to pollutants from either diesel or gasoline-powered engines for independent or simultaneous study. Laboratory animals were exposed for three months to diluted gas from catalyst-equipped gasoline engines to measure pulmonary effects of inhaled combinations of sulfuric acid and metal sulfates. Additionally, direct sulfuric acid mist concentrates in the lung



were measured. The exposure chambers are already contributing to the understanding of the biological impacts of automobile exhausts.

Additional research will continue to improve our understanding of the dynamics and impacts of automotive exhausts.

Three-Way Catalysts

At present, manufacturers are showing increased interest in a system that reduces NO_X, hydrocarbons, and CO emissions all in one step—referred to as the three-way catalytic system. During research in 1977, EPA evaluated the efficiency of the three-way catalysts and tested pollution from them to assure that there is no problem of creating secondary pollutants, as happened in the initial catalytic converters.

The Los Angeles Study

A long-term monitoring study has been initiated by ORD to assess the impact of catalyst-equipped autos on air adjacent to a freeway in Los Angeles. Present findings are as follows:

- The freeway contribution of carbon monoxide (CO) has *decreased* about 25% since 1974. Total suspended particles and lead have both *decreased* approximately 25% since 1975. The current freeway contribution of sulfates to the atmosphere indicates only 0.05 to 1.0 $\mu g/m^3$.

- The levels of NO and NO_2 between 1975 and 1976 have *increased* more than 50%. There is an inadequate amount of O_3 at freeway level to convert all the NO to NO_2.

- The *background* levels of CO, NO, and NO_2 have remained essentially constant since 1974. Background levels of total suspended particles and lead have changed little. However, the background levels of sulfates have *decreased* 25%.

- Weekend lead concentration is about 60% higher at the downwind site than the weekday level.

The following ORD components contributed to the research described above:

OFFICE OF HEALTH AND ECOLOGICAL EFFECTS: • Health Effects Research Laboratory, Research Triangle Park, NC • Health Effects Research Laboratory, Cincinnati, OH

OFFICE OF MONITORING AND TECHNICAL SUPPORT: • Environmental Monitoring and Support Laboratory, Research Triangle Park, NC

OFFICE OF AIR, LAND AND WATER USE: • Environmental Sciences Research Laboratory, Research Triangle Park, NC

coke ovens

Coke-oven emissions can be controlled with ORD - sponsored technology

Uncontrolled emissions from coke pushing

Coke is a coal-derived carbon substance that is an integral part of American steel manufacturing. The emissions resulting from the coke-producing process, however, currently present the most severe pollution problem in the steel industry.

Workers exposed to coke-oven gases show markedly increased incidences of malignant and nonmalignant respiratory diseases. Their cancer risk is estimated at over 100 times normal. The gases from coke ovens not only contain numerous identified carcinogens, but also are composed of such toxic substances as sulfur dioxide, lead, beryllium, and hydrogen cyanide. The general public, particularly the young, the old, and ill persons, have a high risk of chronic bronchitis from these emissions.

ORD has launched a comprehensive program to reduce the emissions associated with conventional coke-making. ORD is also investigating worker job-related health problems.

The essence of the coking process is the heating of carloads of coal in a low-oxygen oven. Coke ovens emit toxic pollutants throughout the production cycle. A large portion of coke-oven emissions are produced when the coal is initially charged (loaded) into the oven. When the coking takes place in the closed oven, the oven often leaks from lid and door seals. Pollutants can also escape when the coke is "pushed" from the coke oven to be cooled in the quenching process. Still more emissions may occur in the quenching of the hot coke. At some stages of the coking process, thick grey billows of smoke escape into the atmosphere.

Emission Control

ORD has already demonstrated a system for controlling coke-oven charging emissions. The resulting charging car contained emissions within the coke oven and at the same time reduced worker exposure to emissions found around the top of the coke oven.

Many features of this first demonstration system have since been incorporated into advanced equipment designs. ORD has also tested and evaluated an advanced

pushing emissions control system. This system captures potential emissions within the coke receiving car. These emissions are then passed through a stationary scrubber and cleansed.

This system has a relatively low cost and can be retrofitted to the majority of existing coke ovens. EPA has kept full operation and maintenance data, and information on the system capture efficiency, as part of the Agency's testing and evaluation process. This information is available to industry to aid in commercial acceptance tests.

A study was also done by ORD of controls on a combined coke pushing and quenching system. The coke is completely enclosed from the time it leaves the oven until it is quenched. Emissions are controlled by a high-energy scrubber mounted on the coke car.

This system can be applied to nearly all new coke ovens. Because more than one-half of existing coke ovens are approaching 20 years old, about 125 coke-oven batteries will have to be replaced in the next 10 years (based on an average life of 30 years). If this control system is incorporated into new plant designs, a substantial step will have been taken in significantly reducing coke-oven emissions.

Control Technology

In 1977, an ORD task force developed technical and economic guidelines for applying control technologies to U.S. coke-oven batteries. Specific control technologies include the smokeless coke-oven charging system, the smokeless pushing system, the enclosed coke pushing and quenching system, and staged charging.

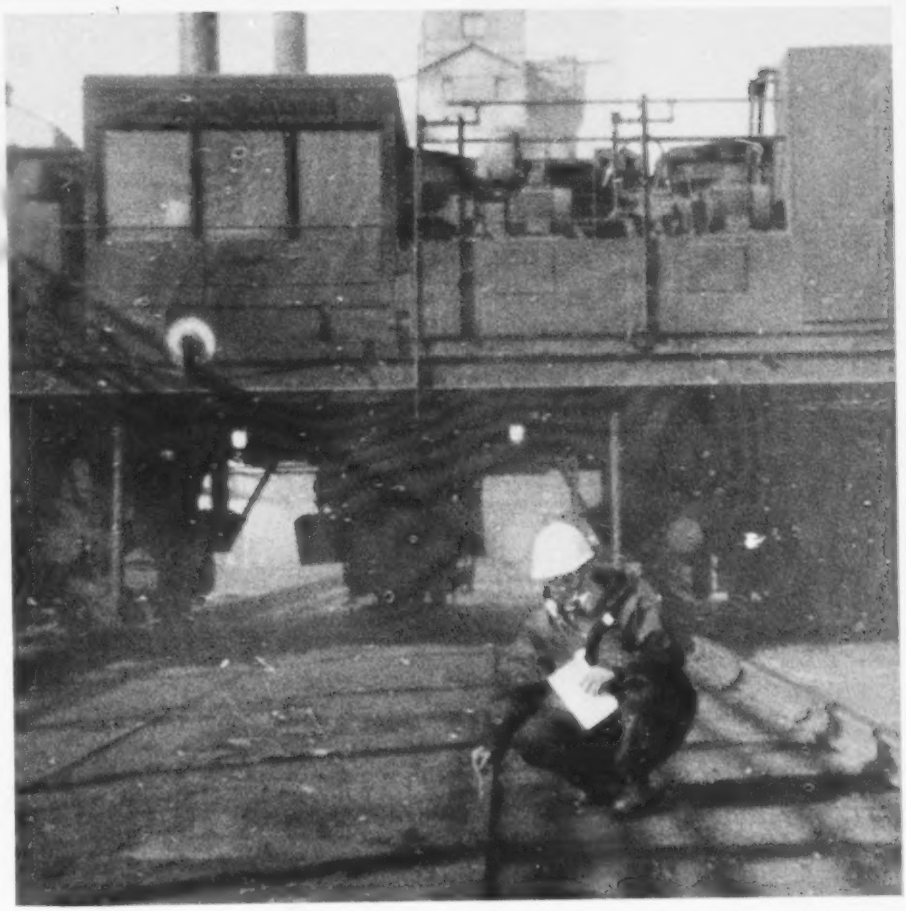
The ORD emissions control demonstrations have generated extensive environmental, economic, and operational data important for successful commercial applications.

ORD is leading other research projects that will quantify coke-oven door emissions and develop improved coke-oven door seals to reduce emissions during the coking cycle. Quenching emissions systems including a dry quenching technique are also being studied.

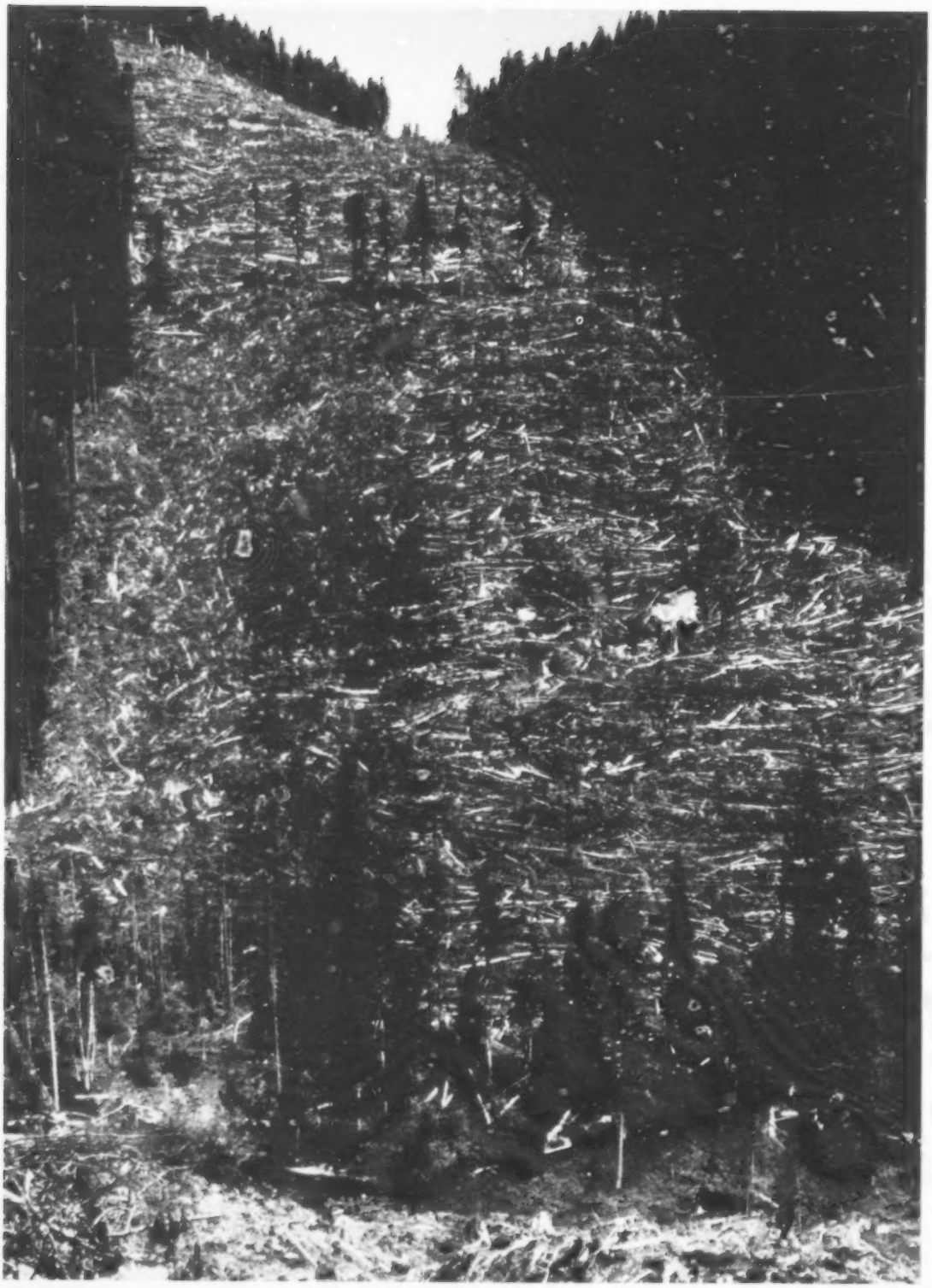
The successful application of emissions control technology to the steel industry is an example of productive ORD/industry cooperation. Through such joint EPA/industry projects, practical technologies evolve to meet environmental needs without imposing excessive costs.

The following ORD components contributed to the research described above:

OFFICE OF ENERGY, MINERALS AND INDUSTRY: • Industrial Environmental Research Laboratory, Research Triangle Park, NC
OFFICE OF HEALTH AND ECOLOGICAL EFFECTS



Emission controls effective in coal charging



CLEAR CUTTING IMPROVEMENT: Rows of mature trees are left perpendicular to the slope of the hill. Such practices reduce the possibility of severe soil erosion.

agriculture

ORD works to identify less polluting ways of managing forests and farms

Water quality goals in many areas cannot be attained because of increasing pollutants from crop, animal, and forest production activities. Given current and projected worldwide demands for food and fiber products, these activities are expected to continue to increase, creating in the process, even more severe environmental problems.

ORD has implemented a series of research efforts to respond to the environmental damage from agriculture and forestry pollutants. Included are problem assessment, development of assessment/prediction models, management practice evaluations, and related support activities.

In 1977, two ORD reports addressing pollution control for forestry production were completed through an interagency agreement with the U.S. Forest Service. One report describes research and development needed to deal with water pollution from forest and rangelands. The other defines the relationships between wildland management practices, nonpoint sources of pollution, forestry management prediction models, and watersheds suitable for model development.

During 1977, ORD held a national conference on Irrigation Return Flow Quality Management. Wide ranging discussions covered such topics as technologies to alleviate irrigated agricultural water quality problems, techniques for improved water management, and irrigation return flow models.

CABLE LIFTS LOGS: A cable lift hoists cut logs out of forest. This technique causes substantially less soil disruption than traditional dragging or tractor skidding of logs.

Assessment/Predictive Models

In 1977, ORD developed two basic mathematical models, with user manuals, to assess the runoff of sediment and agricultural chemicals (pesticides and fertilizer compounds) from land used for crop production. Planners and decision makers are now using these models in developing areawide waste management plans. The models are used to evaluate alternative "best management practice" guidelines, and are applicable to pesticide regulation programs.

Through an interagency agreement with the Bureau of Reclamation, ORD has also developed a mathematical model to predict the mineral quality of return flow water from irrigated crop land. The model can be used for assessing improved irrigation management. Additionally, it can assist in determining the effectiveness of alternative water management methods. Both EPA and the Bureau of Reclamation are currently using this model to evaluate environmental impact statements dealing with water diversion and impoundment projects in the western states.

Management Practices

ORD completed two management practices evaluations in 1977. The first dealt with an integrated system of technological improvements for irrigation return flow salinity in the Grand Valley of Colorado. The approach has been deemed effective in meeting environmental goals. It also serves to highlight socioeconomic concerns that must be dealt with for the approach to be accepted by local citizens. Three reports were generated from the project: the first describes the method for a program to control saline runoff, the second deals with the effect of different irrigation management and control methods on improved water quality, and the third defines techniques for salinity control in the Grand Valley area. Much of the research described in these reports is

applicable to other crop irrigation areas.

The second evaluation was of a runoff control facility designed and constructed for a small cattle feedlot in Nebraska. Results indicate that design volumes for debris basins and holding ponds were effective in controlling runoff from snowmelt and rainfall. The center pivot irrigation system was also shown to be satisfactory for land disposal of the liquid waste material. The management practices developed via this project can be used by small feedlot operators to control pollution from animal wastes.

Support Activities

In 1977, ORD held state-of-the-art seminars in Washington, D.C. for EPA staff and for the personnel of other agencies on nonpoint source modeling and on the management of irrigation return flow water quality. Assistance was provided within EPA to the Office of Water and Hazardous Materials (a guide was prepared to aid in the assessment of the relative importance of nonpoint source pollutants and several national 208 conferences were presented) as well as to regional staff and state and local planning agencies.

The following ORD components contributed to the research described above:

OFFICE OF AIR, LAND AND WATER USE:
- Environmental Research Laboratory, Athens, GA
- Robert S. Kerr Environmental Research Laboratory, Ada, OK

OFFICE OF MONITORING AND TECHNICAL SUPPORT

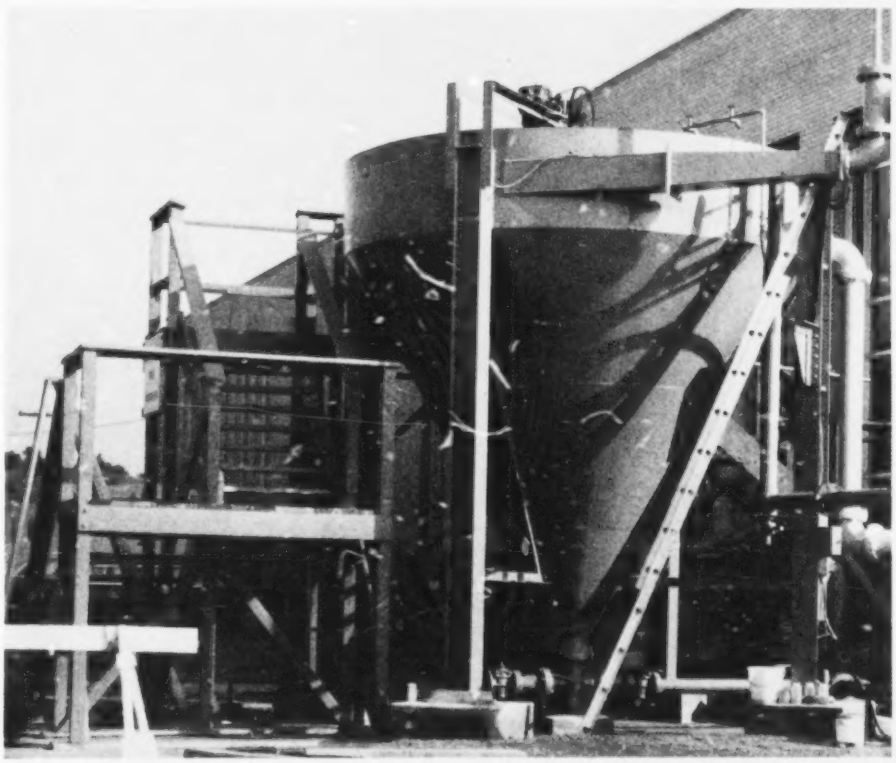
LINING AN IRRIGATION DITCH: Waterproof lining installed in irrigation ditches reduces seepage and water loss. Such linings help control the leaching of salts in underlying soils.

waste management

Research provides methods to control urban runoff, detoxify hazardous wastes

The municipal waste management research program within ORD is designed to help communities comply with EPA regulations on water quality, solid and hazardous waste disposal, and resource recovery and conservation. The main purpose of the program is to develop pollution control technologies, management systems, and assessment methods which states and municipalities can use to meet environmental standards.

In 1977, ORD placed a number of important technological capabilities in the hands of those who provide municipal treatment services. A sewage overflow regulator was developed to reduce the amount of suspended solids entering surface water during storms. Other research was conducted on detoxification of hazardous wastes, wastewater management systems, sediment pollution control, and landfill leachates.



SWIRL CONCENTRATOR: Regulator controls combined sewer/runoff overflow.

The SWIRL regulator

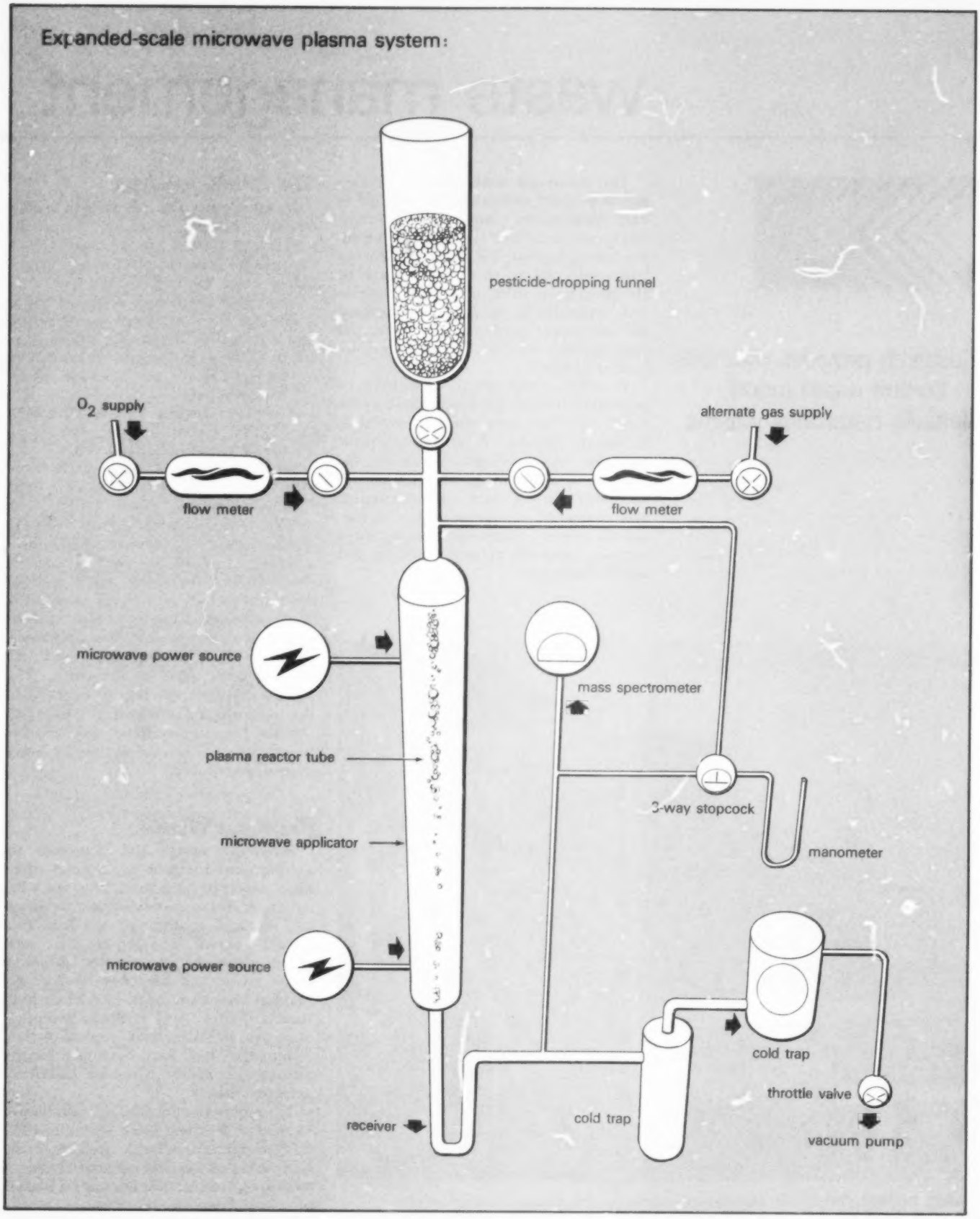
In most cities and towns with sewage treatment systems, water runoff from the streets and storm drains is passed through the sewage treatment plant to be cleansed before being released. During rainstorms or snow melt storm-drain sewage overflow is diverted from treatment plants to surface streams by devices known as regulators. Conventional regulators experience mechanical failures and blockages which can cause sewage to flow directly into surface water systems. These malfunctioning regulators contribute significantly to the overall water pollution problem.

Several years ago ORD began development and demonstration of a new, dual-function regulator called SWIRL. The SWIRL device controls sewage flow and separates solids over a broad range of flow conditions. SWIRL is able to separate about 50% of the sewage solids in short detention periods of seconds or minutes. These solids can then be stored for later treatment during normal flow conditions. SWIRL is also a relatively low cost device that requires little maintenance. The SWIRL regulator will help to solve one of the most nagging problems of controlling combined sewer overflows and reducing the discharge of raw sewage during heavy rains and snow melt.

Hazardous Wastes

Industrial wastes and pesticides requiring detoxification or disposal often have molecular structures that resist destruction. These materials must be properly managed or disposed of safely. Two recently passed laws require that such wastes either be re-used (the Resource Conservation and Recovery Act) or detoxified prior to disposal (the Toxic Substances Control Act). With the exception of expensive incinerator processing, few technologies have been developed for the disposal of highly toxic or extremely persistent wastes.

In order to provide an alternative method of handling these wastes, in 1977 ORD conducted full-scale tests on a new microwave process for detoxification of hazardous wastes. The microwave plasma process subjects hazardous wastes fed into


Expanded-scale microwave plasma system:
pesticide-dropping funnel
O_2 supply
alternate gas supply
flow meter
flow meter
microwave power source
mass spectrometer
plasma reactor tube
3-way stopcock
microwave applicator
manometer
microwave power source
cold trap
throttle valve
receiver
cold trap
vacuum pump

a reactor to intense electron bombardment, which decomposes the wastes into their basic elements. During tests in 1977, the microwave plasma system successfully detoxified the pesticides malathion and kepone, a rodent poison (methyl bromide), two polychlorinated biphenyl (PCB) liquids, and a mercury-containing fungicide.

When compared with standard incinerators, microwave plasma systems have several advantages including portability, relatively low initial cost, and a leak-proof operation which provides the capability for decomposing materials where no other technique is satisfactory. For example, in an ordinary incinerator the decomposition of phenylmercuric acetate could result in an uncontrolled release of mercury metal or oxide particles to the atmosphere. In the plasma system, on the other hand, the mercury is separated from the effluent gas stream and collected. As a result of these advantages, this technology may find applications in hospitals, universities, commercial laboratories and private hazardous waste disposal firms. It promises to be an extremely valuable tool for removing potentially lethal contaminants from the environment.

The burden of developing wastewater management plans falls on state and local planners, who need guidelines and procedures for conducting areawide assessments and, subsequently, for drafting plans. To support the development of such areawide assessments an Urban Planning Task Force was formed within ORD in 1977. The task force provided rapid technological support to EPA's Areawide Water Quality Management Program, and surveyed more than 25 local assessment agencies and other users to develop an effective information delivery system.

In August 1977, the Urban Planning Task Force completed a comprehensive three-volume *Areawide Assessment Procedure Manual* for field use by water pollution control planners, engineers and municipal decision makers. This manual provides a uniform method for areawide assessments and will help to shorten the time between planning and water quality improvement.

Low Volume Flows

Larger cities have already benefited from planning and funding designed to attack the major share of the nationwide water pollution problem. In 1977, ORD increased its attention to the problems of smaller communities, many of which are not served by any centralized sewage collection or treatment system.

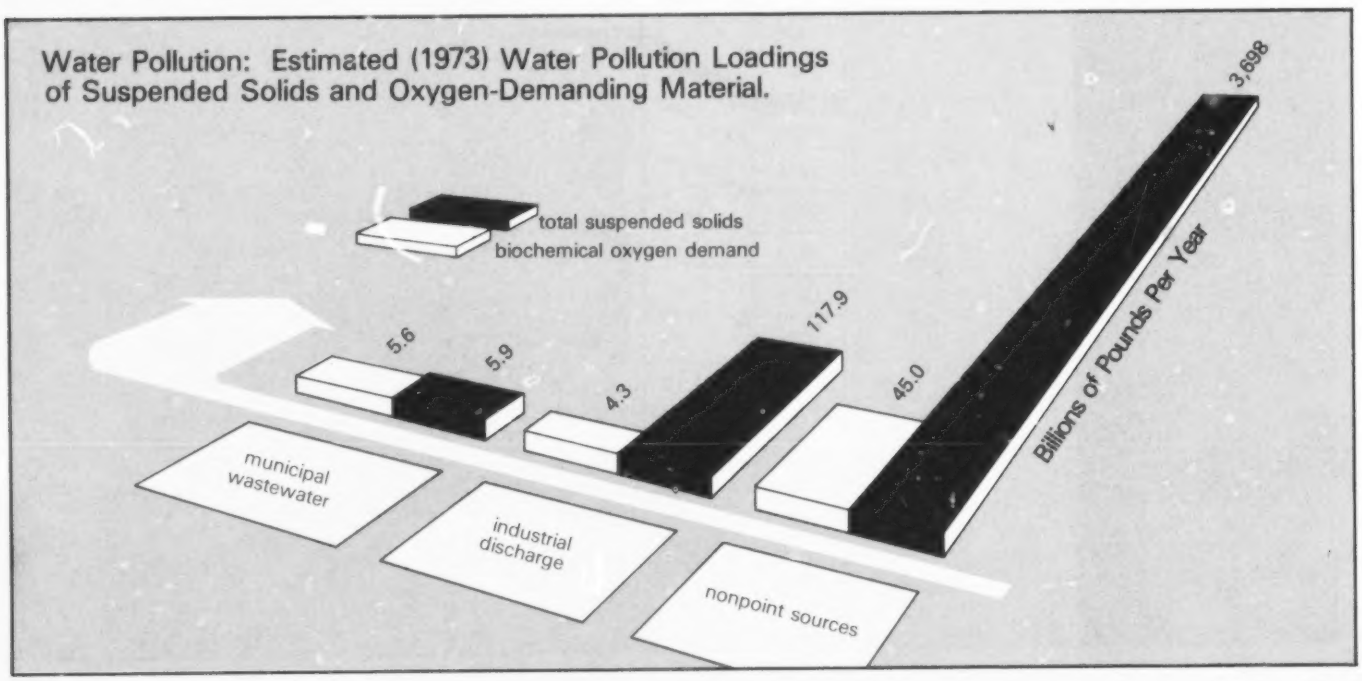
To transmit necessary technology and assistance to small and rural communities, ORD prepared and distributed documents on such topics as *Cost-effectiveness Analysis of Alternatives for Small Wastewater Treatment Systems*, and *On-Site Disposal of Small Wastewater Flows*. ORD also conducted regional seminars and workshops on the problems of small community waste management.

An alternative method of treating wastewater is by land application—using vegetation and the soil to remove contaminants from the wastewater. Land treatment can achieve removal levels that compare favorably with other wastewater treatment methods. The feasibility of land treatment of wastewater has been successfully demonstrated in projects at Bakersfield, California; Muskegon, Michigan; St. Charles, Maryland and Pauls Valley, Oklahoma. EPA Administrator Costle has recently committed the agency to aggressively pursue this energy- and cost-efficient means of wastewater purification. ORD has been assigned the lead role in expanding the applicability and potential of land treatment techniques. Carrying out this assignment, ORD in 1977 published a process design manual for land treatment of municipal wastewater. The manual is a practical design guide which collects all available information on land treatment technology under one cover for use by municipal waste planners.

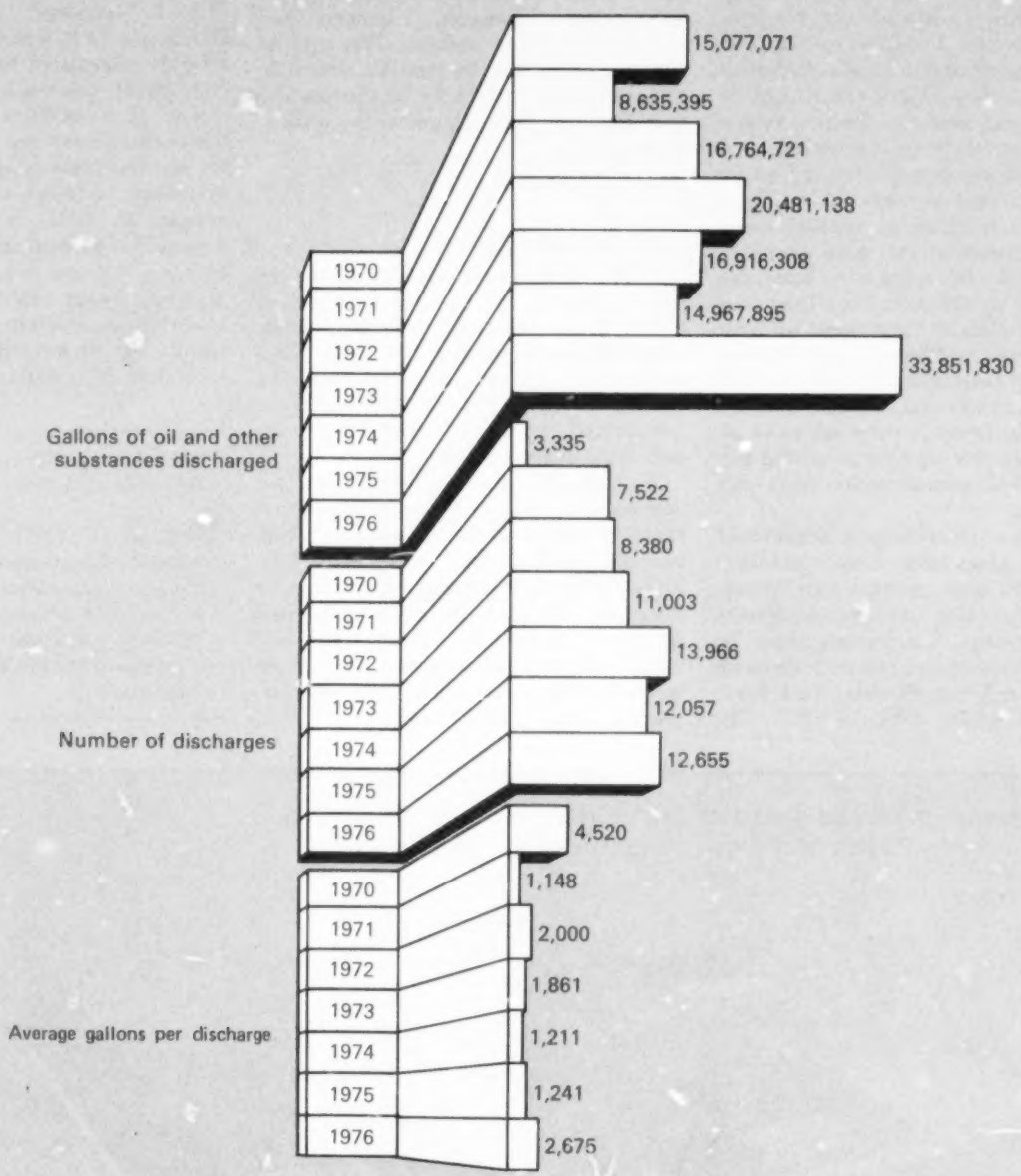
The following ORD components contributed to the research described above:

OFFICE OF AIR, LAND AND WATER USE:

- Municipal Environmental Research Laboratory, Cincinnati, OH
- Robert S. Kerr Environmental Research Laboratory, Ada, OK
- Environmental Research Laboratory, Athens, GA



National Spills Summary



spills

An on-site ORD team improves control and clean-up methods for hazardous spills

Nearly three billion tons of potentially hazardous materials are produced and handled annually in the United States. More than one million tons of these materials escape annually into the environment, through some 5,000 to 10,000 transportation accidents, pipeline breaks, lagoon ruptures, floods, and intentional dumpings.

The ORD Response

The ORD's oil and hazardous materials spills team responds to actual spills to improve detection and control techniques and to provide data on the impacts of such events. This team works hand in hand with the U.S. Coast Guard and Navy to control, remove, and recover spilled oil and chemicals.

When a spill occurs, ORD's technical team moves on request to the site to collect and analyze samples. Depending on the nature of the spill, ORD may then bring in its own portable "mobile spills laboratory," and may call for its physical-chemical treatment trailer to decontaminate dangerous liquids.

The mobile spills laboratory allows quick, accurate, on-site analysis of the spilled substance, and avoids potentially harmful delays involved in shipping samples to and from the scene. The mobile laboratory employs a variety of sophisticated analytical techniques, including computerized gas chromatography; atomic, infra-red, and fluorescence absorption spectrophotometry; and the full range of standard wet-chemistry methods.

The portable physical-chemical treatment trailer is effective in the decontamination of medium-sized spills. This system contains three mixed-media filters for the removal of suspended or precipitated material and three activated carbon columns for the adsorption of many soluble organic chemicals. The system includes a 15,000-gallon rapidly deployable portable tank, where contaminated liquids can be mixed with chemicals designed to flocculate, precipitate, or neutralize the hazardous substances. It also has several 3000-gallon "pillow" tanks for the storage of decontaminated effluent.

The Argo Merchant

UPI Photo

Major Spills Treated

The ORD spill team has refined its spill response procedure and technology over the years since its inception in 1971. In 1977, the team responded to several oil and chemical spills:

- In Oswego, New York, an industrial waste disposal facility was abandoned. By the spring of 1977, a lagoon on the facility site containing more than 400,000 gallons of chemicals and wastewater was flooding via Wine Creek into Lake Ontario. The ORD mobile spills laboratory was sent to the site, where investigators found a high concentration of polychlorinated biphenyls (PCBs) in the floating organic chemical layer that was oozing from the lagoon. Direct contact with PCBs can cause sickness, skin disease,

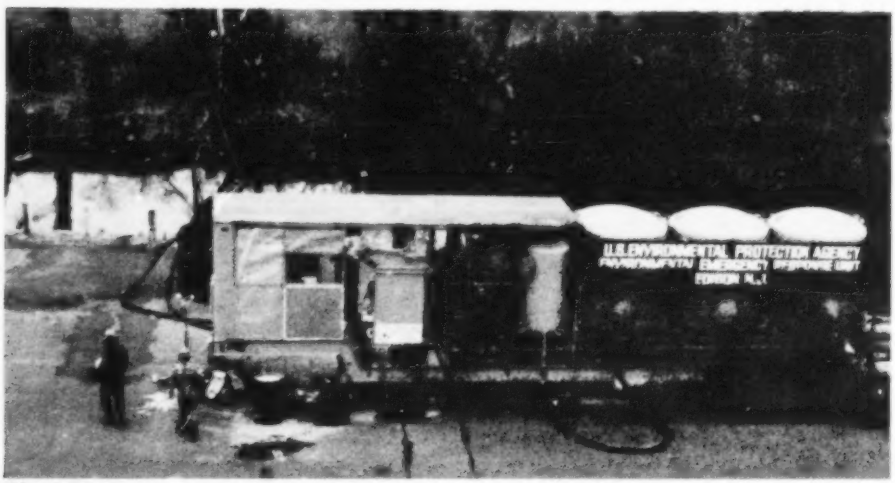
and stunted growth. The 400,000 gallons of mixed waste were treated and decontaminated, ending a substantial problem in the Lake Ontario feed stream.

- In Dittmer, Missouri, rainwater overflowed from a pit that had been used as a dumping site for chemical waste. The effluent contaminated a nearby water supply feed stream. The ORD responded in a clean-up effort, which involved excavation and disposal of the contaminants in the pit, treatment of the stream water with the EPA portable physical-chemical treatment system, and design and installation of a field-improvised carbon treatment system for stream water decontamination that could operate after the mobile treatment system was removed.

New Technology

ORD is concerned not only with action in emergency situations but also with the development of new technology to improve the capacity to contain and treat spills of hazardous materials. To simulate oil tanker spills, ORD operates the oil and hazardous materials simulated environmental test tank at Leonardo, New Jersey. The tank is an environmentally safe site where new techniques for containment and treatment can be tried. The tank is nearly 700 feet long and 65 feet wide, big enough for a 17-ton ship and a simulated oil slick with waves 2.5 feet high and 80 feet long. The test tank has proven to be extremely valuable for research. Oil-containing devices, chemical dispersants, and other methods developed and proven by ORD have already saved beaches from oil spills. A major concern in spill management is the safety and well-being of emergency personnel. Joint efforts with the U.S. Army Natick Laboratories resulted in an ensemble consisting of rebreathing apparatus, a head/torso cooling system, and a quick-donning butyl rubber protective suit.

In addition, under the Federal Spill Program, EPA has been instrumental in developing, with the U.S. Coast Guard, means of preventing oil spills. One of these activities is the development of regulations that call for a Spill Prevention, Control and Countermeasure (SPCC) Plan to be prepared by any facility that could reasonably be expected to spill oil into U.S. waters—such facilities include those with total buried storage greater than 42,000 gallons, total nonburied storage greater than 1,320 gallons, and those with a single container that holds more than 660 gallons. EPA and the U.S. Coast Guard also conduct aerial surveillance of coastal and inland waters to check operations and maintenance of harbor areas and industrial oil-handling facilities. ORD has also developed a course in oil pollution control. This course is aimed at informing those individuals and organizations responsible for maintaining the Nation's waterways and coastal areas.



The ORD Emergency Spills Response Unit

Sources of Oil in the Oceans

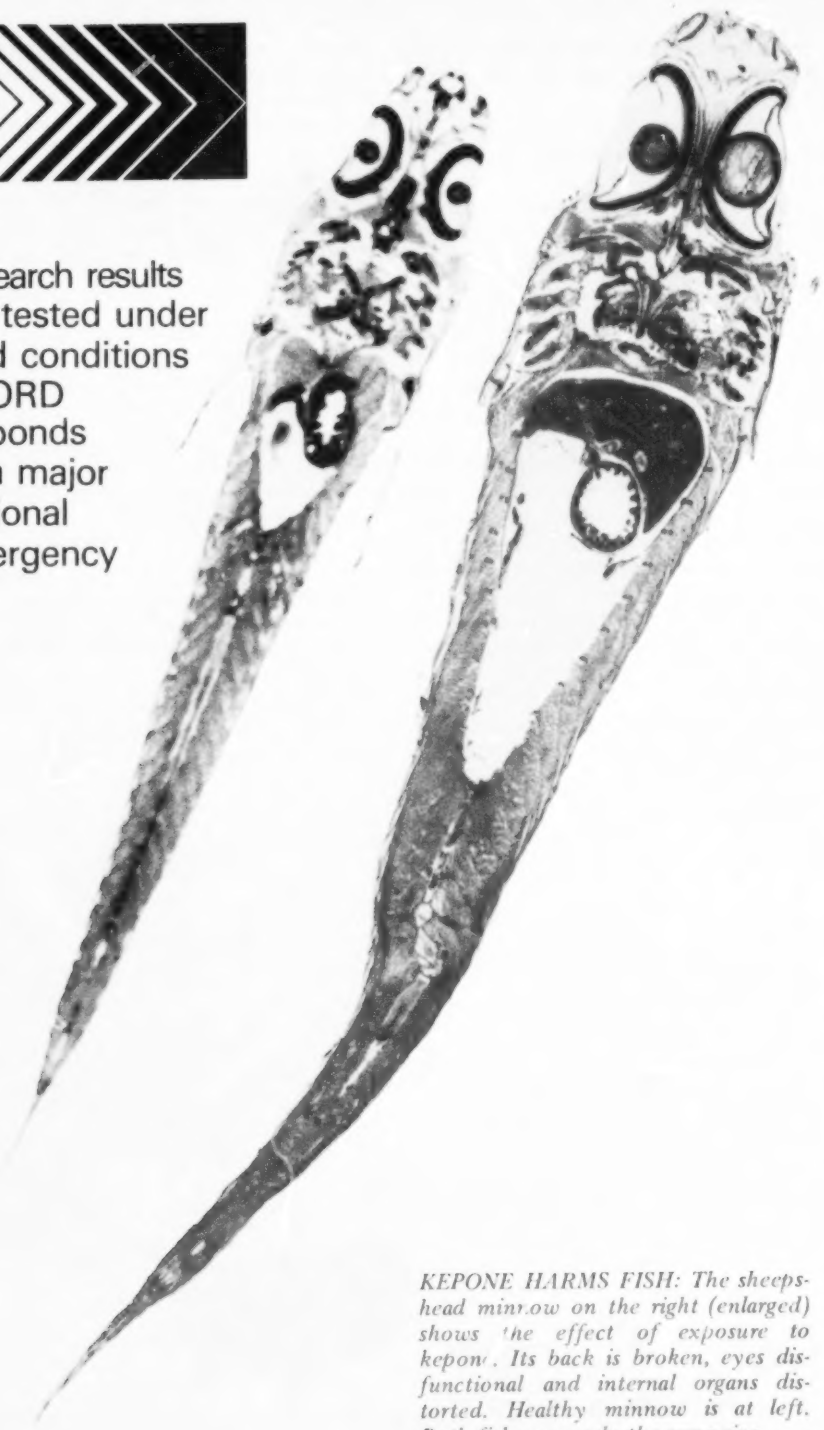
Source	*Estimated Contribution (Tons/Yr)*	*(%)*
Transportation Tankers, Dry Docking, Terminal Operations, Bilges, Accidents	2,350,000	34.9
Coastal Refineries, Municipal and Industrial Waste	875,000	13.0
Offshore Oil Productions	87,500	1.3
River and Urban Runoff	2,100,000	31.2
Atmospheric Fallout	660,000	9.8
Natural Seeps	660,000	9.8
TOTAL	6,732,500	100.0

The following ORD component contributed to the research described above:

OFFICE OF ENERGY, MINERALS AND INDUSTRY: • Industrial Environmental Research Laboratory, Cincinnati, OH (Edison)

kepone

Research results are tested under field conditions as ORD responds to a major regional emergency



KEPONE HARMS FISH: The sheepshead minnow on the right (enlarged) shows the effect of exposure to kepone. Its back is broken, eyes disfunctional and internal organs distorted. Healthy minnow is at left. Both fish are nearly the same size.

In August 1975, a physician diagnosed neurological disorders in an employee of a chemical processing plant in Hopewell, Virginia. The symptoms were directly linked to the pesticide kepone, produced at the plant. The Virginia Health Department called in ORD health effects research specialists to evaluate the threat to health and environment caused by the presence of kepone. Hopewell, site of the kepone plant, is located near the James River which flows into the Chesapeake Bay, both major commercial fisheries.

Kepone is a polychlorinated hydrocarbon that degrades very slowly in the environment and stubbornly resists efforts at destruction or decomposition. It is highly toxic to animal life, is a suspected carcinogen, and has produced severe growth abnormalities in laboratory test animals.

In response to the emergency, ORD cooperated with the Center for Disease Control to assess population exposure to kepone. Of 214 community residents surveyed, 40 (19%) had detectable levels of kepone in their bloodstreams.

ORD researchers made an initial assessment of the damage. To support this assessment, ORD scientists developed highly sophisticated methods for detecting kepone in various media. They discovered that kepone was widely dispersed in the Chesapeake Bay region and began immediately to determine the effect of the pesticide on terrestrial and marine ecosystems in the area. In response to the crisis, the Governor of Virginia banned fishing in the James River. The plant itself was shut down and dismantled.

Scientists from ORD joined a cooperative research effort involving other federal and state agencies. ORD researchers suspected that the kepone had spread, not only to the fisheries of the James River estuary and the Chesapeake Bay, but into the Atlantic Ocean as well. Commercial marine species, such as crab and shrimp, were gathered and examined in laboratory tests to determine the degree of contamination. This information was used to assure that no contaminated seafood was sold and that affected fishing areas remained closed.

Kepone uptake and concentration was measured in seed oysters and other shellfish, estuarine algae, mollusks, crustaceans and fish. Accumulations of kepone exceeding 1 ppm were found in many of the samples taken. At this concentration, the kepone in the food chain appears to pose a major threat to human life. In addition, results from studies of the natural flows of the James River and the Chesapeake Bay showed that the kepone would be present for some time if no clean-up actions were taken.

The Kepone Clean-up

There is no standardized or approved method for cleaning up such kepone contamination. A method was, therefore, improvised using the best technology and data available. The clean-up was organized by priorities, moving outward from the principal source so that cleaned areas would not be recontaminated. First priority was assigned to decontaminating the homes, land, lagoon, and fixtures on and near the plant site. Second priority was assigned to tank cars and drums containing heavy concentrations of kepone waste at the plant. Third priority was given to the James River and estuary.

The ORD hazardous materials spills treatment trailer was dispatched to the plant site to begin decontamination of about 200,000 gallons of concentrated kepone-water mixtures contained in 14 railroad tank cars and 3 concrete basins at the plant site. As the waste material moved through treatment systems of the trailer, concentrations of kepone were reduced to a level that allowed environmentally safe disposal by the state of Virginia.

The EPA kepone task force participated in other phases of the clean-up, including:

- Drum enclosure of sludge with kepone concentrations of from 1 to 700,000 ppm.
- Enclosure of plant debris in plastic and clay materials suitable for use as landfill.
- Vacuuming, washing, and dry cleaning of homes and areas near the kepone plant.

The kepone clean-up is an ongoing effort. ORD researchers are especially concerned with land contamination and leaching of kepone into adjacent soil and water. Studies are underway to determine the cost of various methods of dealing with land contamination, including removal of soil, burning of contaminated debris, chemical surface fixation, bacterial degradation, and at-sea incineration.

Plans for dredging the James River are being developed and ORD is assisting the state of Virginia in determining how best to destroy the kepone taken from the plant site. In addition, EPA Administrator Costle has been asked to act on a request from the Allied Chemical Company to approve a permit to incinerate, at sea, some remaining kepone and kepone-contaminated wastes. An ocean-going incinerator ship, partly sponsored in the past by ORD and described in the industrial toxics section of this report, would be used for the incineration.

The kepone episode at Hopewell presented ORD scientists with an important challenge. Their response has produced new data that helps to guard against future disasters involving release of toxins and pesticides. ORD researchers have learned how kepone acts on plant and animal life, and how it can be contained, removed from the environment, and ultimately destroyed. The lessons learned will be valuable if and when other chlorinated hydrocarbons pose a threat to the environment.

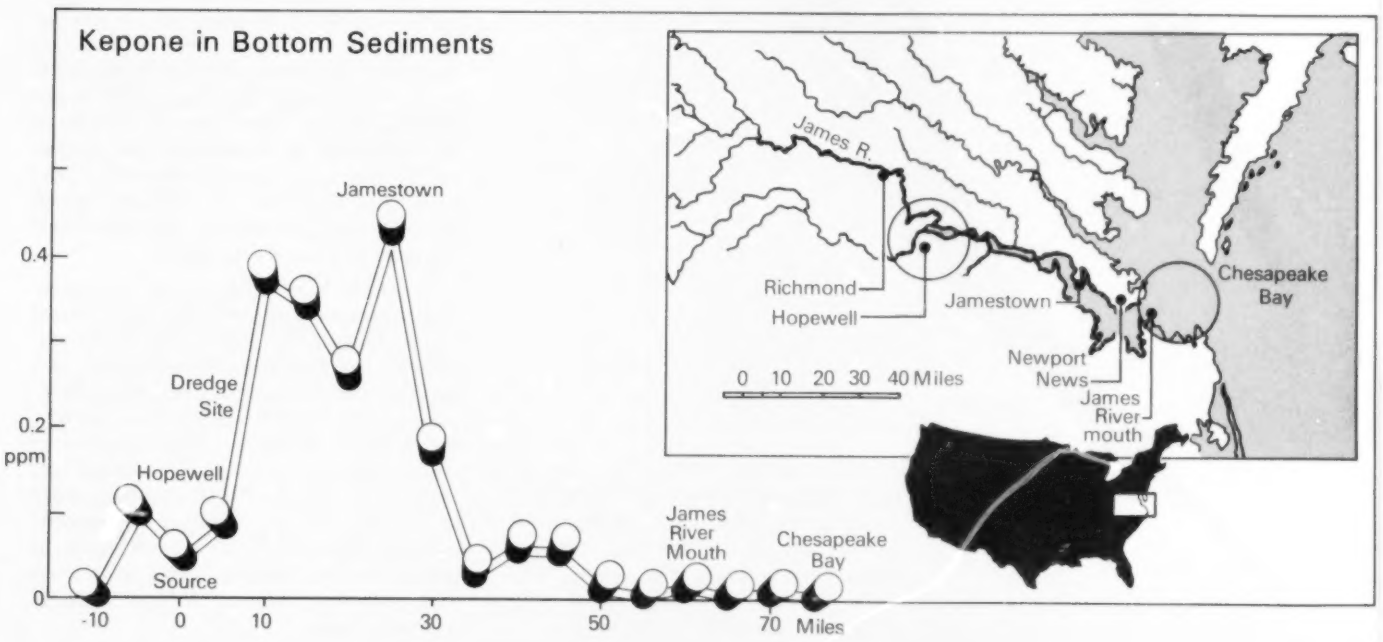
In the meantime, ORD will continue to lend assistance to the clean-up effort in Virginia, and to study the long-term effects of kepone in this assaulted ecosystem.

The following ORD components contributed to the research described above:

OFFICE OF ENERGY, MINERALS AND INDUSTRY: • Industrial Environmental Research Laboratory, Research Triangle Park, NC • Industrial Environmental Research Laboratory, Cincinnati, OH (Edison)

OFFICE OF HEALTH AND ECOLOGICAL EFFECTS: • Environmental Research Laboratory Gulf Breeze, FL • Health Effects Research Laboratory, Research Triangle Park, NC

OFFICE OF MONITORING AND TECHNICAL SUPPORT: • Environmental Monitoring and Support Laboratory, Las Vegas, NV



drinking water

ORD provides data for the regulators and technology for the suppliers

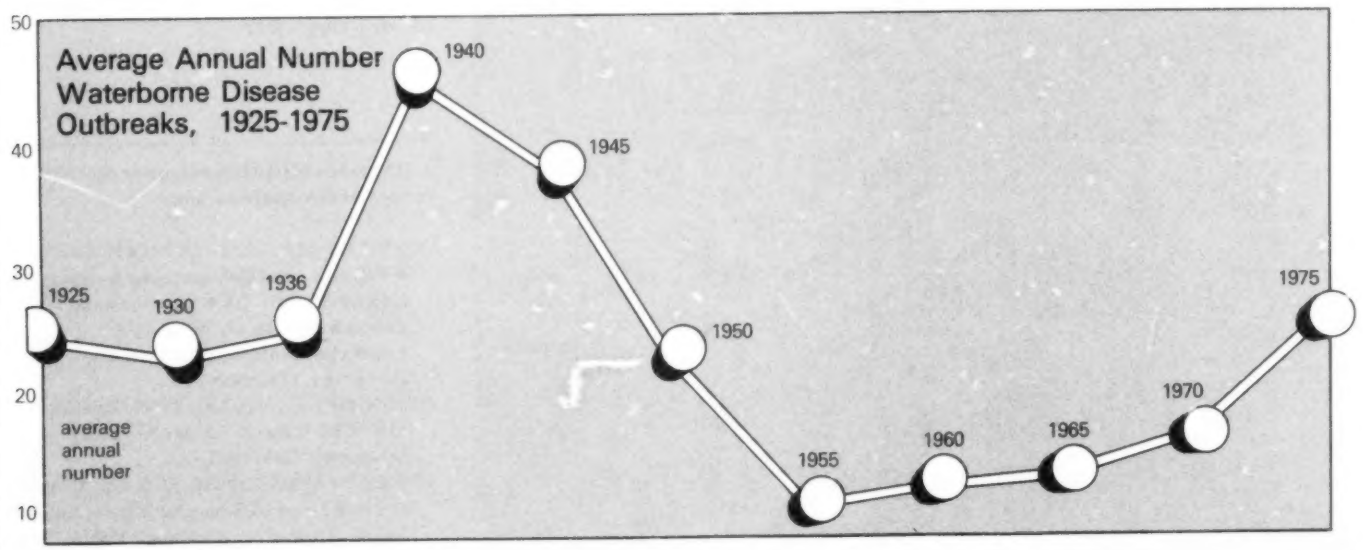
Only in the last few years have techniques and equipment become available to detect and measure very small quantities of contaminants in drinking water. With this more sophisticated equipment, potentially hazardous organic materials were discovered in many of the Nation's water supplies. In response to this problem, Congress passed the Safe Drinking Water Act in December of 1974. That act directed the EPA to establish minimum national standards for drinking water and specific limits for contaminants. Such standards must be met by every community water system supplying more than 15 outlets or 25 people.

Within EPA, the Office of Water Supply is responsible for the development and implementation of drinking water standards. ORD is responsible for providing the scientific information upon which viable standards can be based. In developing standards, contaminants in drinking water must be identified and quantified, and the health effects of these contaminants assessed and balanced against the economic consequences of controls. Methods to increase the efficiency of water treatment must also be developed, as well as ways to provide water suppliers with the know-how and technology necessary to implement new methods of treatment. In addition, ORD is also required to assure that measurements and analyses used to determine compliance with regulations be done in a scientific, legally defensible manner.

In June 1977, EPA Interim Primary Drinking Water Regulations became effective. These regulations establish maximum contaminant levels for 10 chemicals, 6 pesticides, bacteria, radioactivity, and turbidity. These interim regulations will be merged with more complete data to yield revised national regulations.

ORD's job in supporting the interim regulations did not end with their promulgation. In 1977, ORD made considerable contributions to assist compliance with the standards by local and community water suppliers. To aid these suppliers, ORD initiated a program for the approval of alternative test procedures for monitoring. ORD also published a *Manual of Treatment Techniques for Meeting the Interim Primary Drinking Water Regulations.*

In addition to monitoring capabilities, water suppliers need adequate laboratory facilities for the analysis of water quality. In 1977, ORD published an interim manual describing evaluation procedures and minimum technical requirements recommended for certifying laboratories to analyze public drinking water supplies. ORD also trained chemists and micro-



biologists from the EPA Regional Offices and states to evaluate and certify laboratories. As a result, every EPA Region is now staffed with individuals who can certify laboratory facilities and train others to do the same.

Revised Primary Regulations

EPA is now preparing Revised Primary Drinking Water Regulations. In laying the groundwork for these more comprehensive rules, the ORD research program has been developing scientific information for several years. In 1977 ORD's research provided:

- Review of the causes of waterborne disease.
- Examination of the relationship between drinking water constituents and cardiovascular disease.
- Study of the effect of lead on the central nervous system.
- Study of the relationship between cadmium/lead contamination and the human immune response system.
- Report on the health effects of nitrates in drinking water.
- Study of the possible health hazards involved in using asbestos-cement pipes to transport drinking water, and development of means to remove asbestos particles from drinking water.
- Study which showed that little or no health hazard results from passing drinking water through pipes made of polyvinyl chloride.

As it did with the interim regulations, ORD will continue its research to describe practical means for water suppliers to comply with the revised national regulations.

Trihalomethanes in Water

Trihalomethanes have been linked to animal cancers, and epidemiological data suggest they may contribute to cancer in humans. Trihalomethanes form in drinking water from the chemical interaction between chlorine, used as a disinfectant, and organic substances that occur naturally in drinking water sources. Regulations limiting the trihalomethane content of drinking water are now being considered.

In 1977, ORD produced several studies, some in cooperation with the National Institutes of Health, further describing the link between trihalomethanes and cancer. These reports describe the relationships among chlorination, trihalomethane concentration and incidence of cancer. ORD also investigated two techniques for sampling and analyzing trihalomethanes in water.

While ORD is examining the possible links between trihalomethanes, chlorination and cancer, it is also exploring possible alternatives to the use of chlorine as a disinfectant in drinking water. An alternative disinfectant, if developed, may solve the trihalomethane problem without loss of the considerable benefits that chlorination has bestowed.

Protecting Underground Water

Underground water supplies may be contaminated by polluted surface water, leaching, injection of waste, and other means. Under its mandate from the Congress, EPA will soon issue Underground Injection Control Regulations. To aid in implementing these regulations, ORD prepared a guidebook on the technology of injection well construction and maintenance. It also devised sampling methods to analyze the purity or relative contamination of subsurface water sources and studied the impact of unsealed abandoned wells on underground water supplies.

In summary, ORD has developed an extensive support program for the Safe Drinking Water Act. It has carried out the research to produce information necessary for the development of drinking water standards. Beyond providing support to EPA's regulatory activities, ORD has pioneered new methods for cleansing and preserving water supplies. Moreover, it has made its findings, technology, and resources available to water suppliers to enable them to comply with the regulations and to ensure the healthfulness of our drinking water.

Limits Set by Interim Regulations

Constituent	*Level, mg/l unless specified*
Inorganic chemicals	
Arsenic	0.05
Barium	1
Cadmium	0.010
Chromium	0.05
Lead	0.05
Mercury	0.002
Nitrate (as N)	10
Selenium	0.01
Silver	0.05
Fluoride	1.4-2.4*
Turbidity	1 Tu up to 5 Tu
Coliform bacteria	1 per 100 ml (mean)
Organic chemicals	
Endrin	0.002
Lindane	0.004
Methoxychlor	0.1
Toxaphene	0.005
2,4-D	0.1
2,4,5-TP (Silvex)	0.01
Radionuclides	
Radium 226 and 228 (combined)	5 pCi/l
Gross alpha particle activity	15 pCi/l
Gross beta particle activity	4 millirem/year

*Based on annual average temperature.

The following ORD components contributed to the research described above:

OFFICE OF AIR, LAND AND WATER USE:
- Robert S. Kerr Environmental Research Laboratory, Ada, OK
- Environmental Research Laboratory, Athens, GA
- Municipal Environmental Research Laboratory, Cincinnati, OH

OFFICE OF HEALTH AND ECOLOGICAL EFFECTS:
- Health Effects Research Laboratory, Cincinnati, OH

OFFICE OF MONITORING AND TECHNICAL SUPPORT:
- Environmental Monitoring and Support Laboratory, Cincinnati, OH

toxics

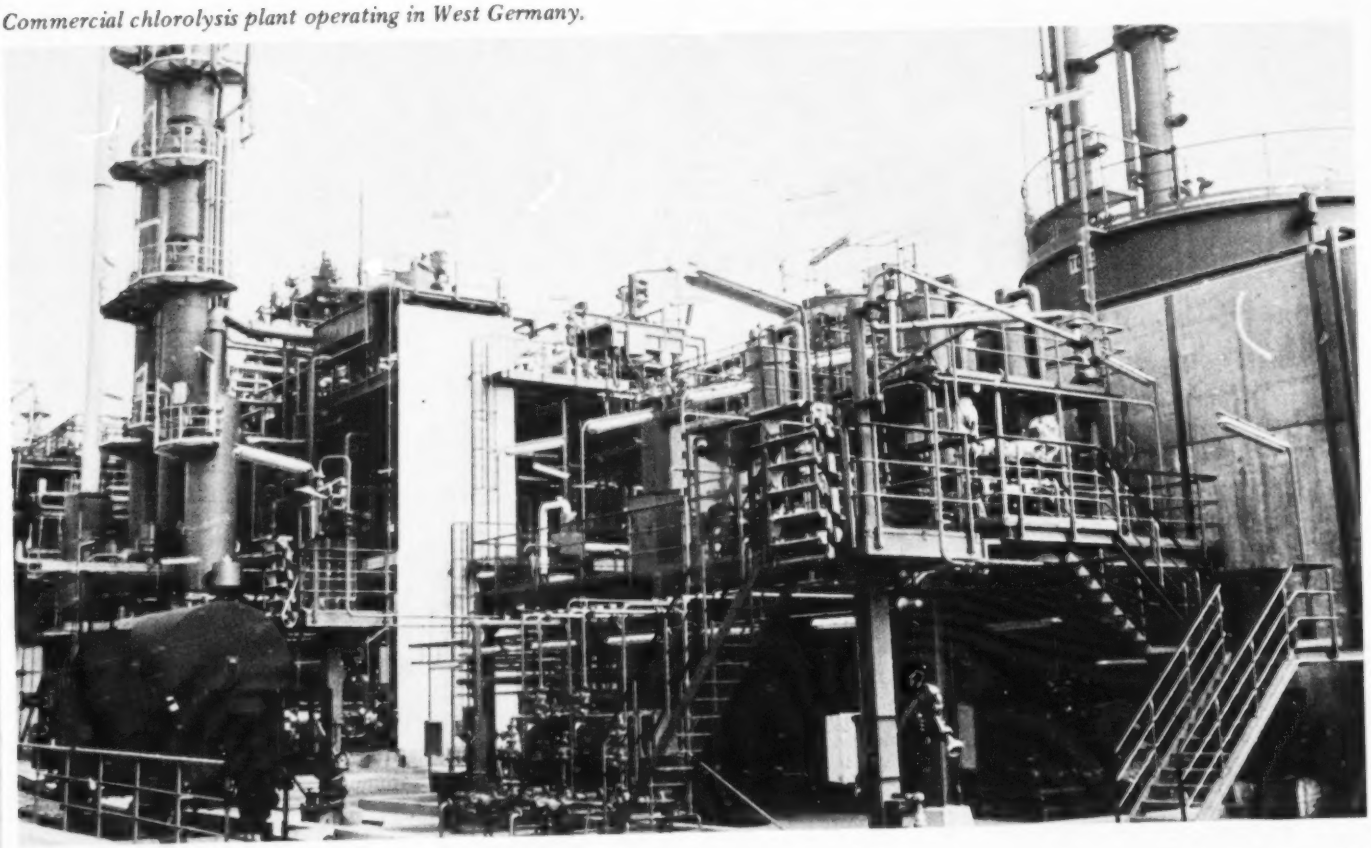
Toxic industrial residues can be managed and destroyed using ORD-sponsored technologies

Every year manufacturers of petrochemical solvents, synthetic fibers, plastics, and pesticides produce 100,000 tons of toxic, chlorinated hydrocarbons chemical wastes. Methods for safe disposal of these wastes have been limited, at best, in the past. Recently, however, two new technologies have proved successful in eliminating these residues. These ORD-sponsored techniques are called chlorolysis and ocean incineration.

Chlorolysis

Ideally, new pollution control technologies should not merely eliminate pollutants; they should also convert them to usable materials. The chlorolysis chemical process converts toxic chlorohydrocarbon wastes to carbon tetrachloride, a usable product in the chemical market.

Commercial chlorolysis plant operating in West Germany.



Chlorolysis uses a combination of distillation, high temperature, and high pressure to convert chlorinated hydrocarbon wastes into (mainly) carbon tetrachloride and anhydrous hydrogen chloride.

The chlorolysis process and its technology transfer are of continuing interest to ORD because of the process' significant advantages, namely:

- The process productively recycles wastes rather than discarding them, thereby reducing consumption of the petroleum feedstocks from which the original residues were derived.
- Little energy is consumed in the conversion process, and the energy value of the original petroleum feedstock is not completely lost.
- The system is essentially closed and only water and carbon dioxide are released to the environment.
- A negligible amount of incineration results in few residues and other associated waste products.
- The process is useful in a regional toxic waste recycling center. The Gulf Coast area generates more than 50% of all U.S. toxic wastes that are suitable for chlorolysis. Thus, a plant located between Houston and New Orleans could serve the toxic waste treatment needs of that region's petrochemical industries.
- Chlorolysis will help EPA attain its goal of reducing toxic discharges to the nation's waters and oceans.

ORD has contracted with a private firm to conduct bench-scale tests of the chlorolysis process on combinations of Herbicide Orange, vinyl chloride monomer, and chlorinated solvent wastes. (They concluded that only 5% of the total feed material should include wastes from pesticide and herbicide plants.) This mixture would also reduce the corrosion on the chlorolysis equipment to an acceptable level.

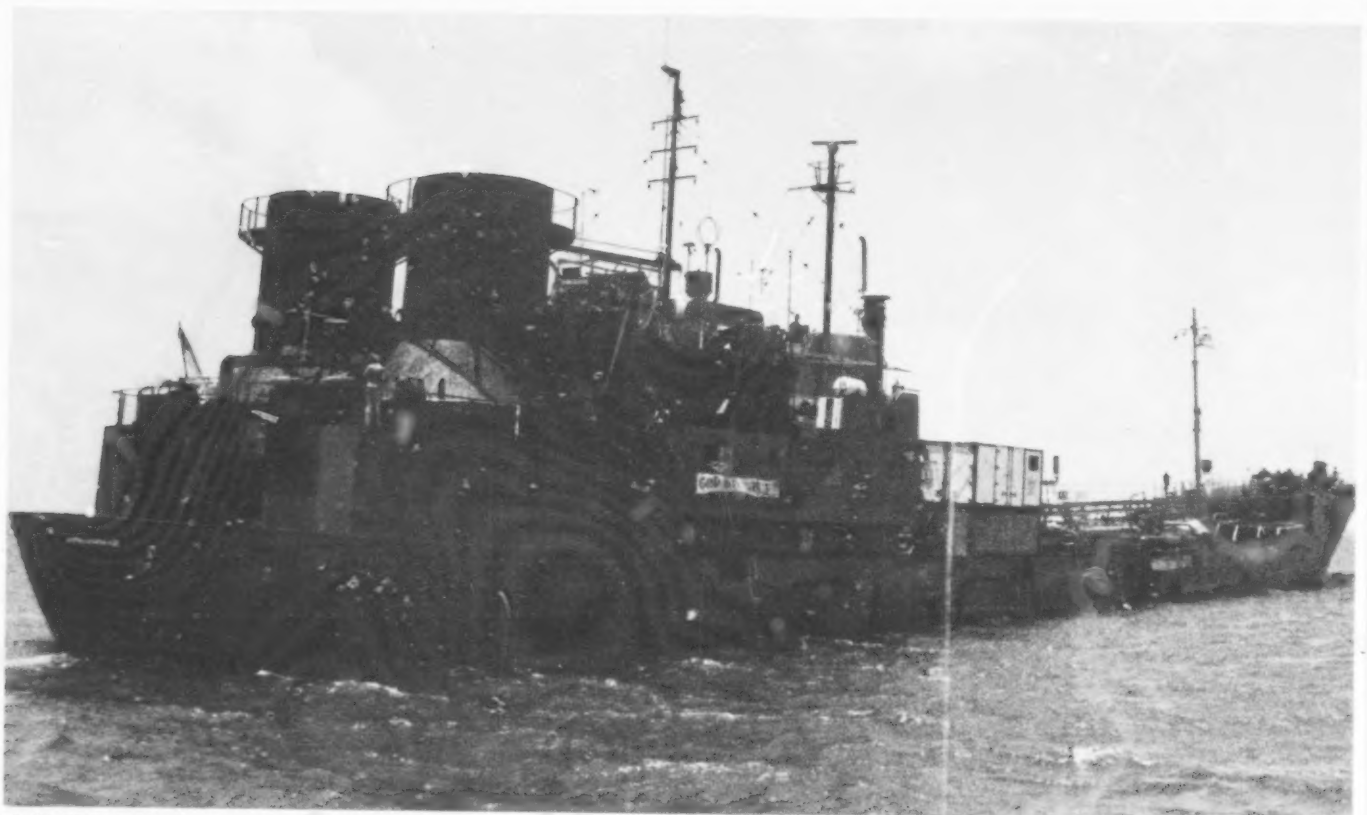
The contractor is currently operating one commercial (50,000 metric tons of carbon tetrachloride) chlorolysis plant in Germany and has sold another plant to the Soviet Union.

Results of 1977 chlorolysis studies indicate that:

- More than 190 million pounds per year of toxic wastes are suitable for chlorolysis feedstocks.
- 109 million pounds of waste residues are produced in the Gulf Coast region each year.
- Assuming the fluorocarbon market continues to grow, the carbon tetrachloride produced by chlorolysis plants can be assimilated by the market.
- A regional waste disposal unit using chlorolysis and other ancillary processes for the Gulf Coast region would cost between $10 million and $30 million.

Ocean Incineration

ORD has also cooperated with industry to develop at-sea incineration—another method of waste disposal. Liquid wastes are burned at temperatures exceeding 1200°C in incinerators installed on especially designed ships.



THE VULCANUS, a floating incinerator ship, can safely burn hazardous materials far from shore.

In March 1977, a second test took place on the Vulcanus. More sophisticated sampling and monitoring techniques were employed to ensure a representative sampling of emissions. An on-line laboratory monitored carbon monoxide, carbon dioxide, total hydrocarbons, oxides of nitrogen, and oxygen concentrations. A solid resin module was employed to trap organic vapors remaining in the combustion effluent. Lower molecular weight species were also trapped.

Results from the 1977 test demonstrate that waste destruction efficiencies consistently exceeded 99.92%. Based on carbon monoxide and carbon dioxide measurements, the incinerator's overall combustion efficiency was 99.96% or more.

Disposal of Herbicide Orange

Early in 1977, the U.S. Air Force petitioned EPA to grant a permit to incinerate approximately 2.3 million gallons of Herbicide Orange contaminated with an average of 2 parts per million of dioxin (TCDD). Dioxin is one of the most toxic herbicides known. It is also a powerful teratogenic (fetus-deforming) substance. In July, the Vulcanus left Johnston Island for the Pacific Burn Test Site about 950 miles west of Hawaii. Testing was concluded in September 1977. Sampling and analysis for the Herbicide Orange incineration program were similar to that of the second Gulf of Mexico test, but because of the highly hazardous nature of the waste, the test planning was even more detailed and exhaustive.

Preliminary results indicated that overall combustion efficiency of both incinerators was consistently 99.99%. Destruction of the contaminant dioxin was in excess of 99.9%.

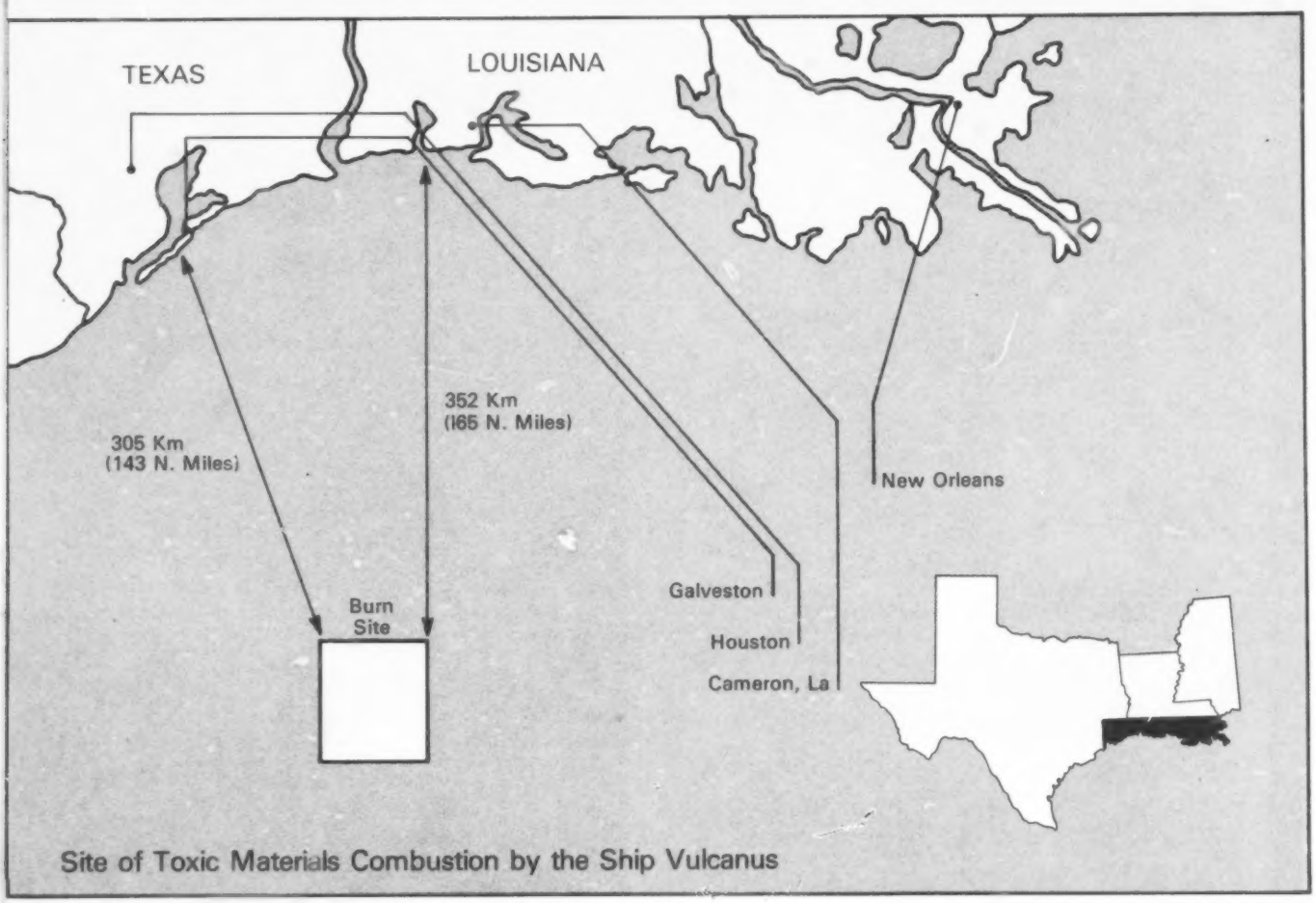
1977 results are based on data from the Vulcanus, which burns only liquid waste materials. For future work, EPA may use the Matthias III, a motor tanker approximately five times the size of the Vulcanus, with an incinerator that can incinerate drummed solid wastes as well as liquids. Planning is now in progress for ORD to evaluate the efficiency of this incinerator for burning both types of wastes.

The following ORD components contributed to the research described above:

OFFICE OF ENERGY, MINERALS AND INDUSTRY: • Industrial Environmental Research Laboratory, Research Triangle Park, NC • Industrial Environmental Research Laboratory, Cincinnati, OH

OFFICE OF MONITORING AND TECHNICAL SUPPORT: • Environmental Monitoring and Support Laboratory, Las Vegas, NV • Environmental Monitoring and Support Laboratory, Research Triangle Park, NC • Environmental Monitoring and Support Laboratory, Cincinnati, OH

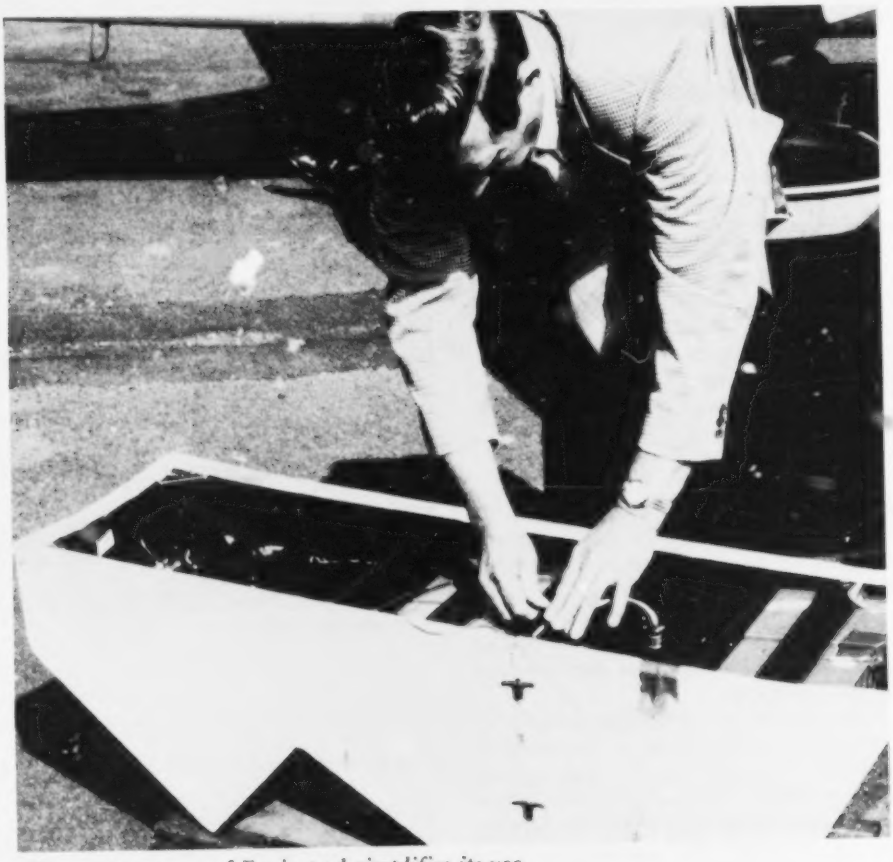
OFFICE OF AIR, LAND AND WATER USE: • Environmental Research Laboratory, Athens, GA • Environmental Sciences Research Laboratory, Research Triangle Park, NC



Site of Toxic Materials Combustion by the Ship Vulcanus

enviropod

Airborne cameras improve speed and cut costs of monitoring



The compactness of Enviropod simplifies its use.

To ensure compliance with its regulatory standards, it is EPA's responsibility to monitor the environment. The use of aerial photography and remote sensing systems is a cost-effective way to carry out that responsibility. One such system is the Enviropod, the product of joint ORD work with the U.S. Air Force Avionics Laboratory.

The Enviropod produces high quality aerial photography over small areas. The Avionics Laboratory designed the system in two, luggage-size sections to ease handling and shipment. The sections are mated and installed as a unit on a small aircraft. Each section has a camera bay and space for batteries. Currently, the Enviropod uses 70-mm format cameras, but existing configurations can be modified to support fast response TV monitors and scanners that are sensitive beyond the visual spectrum.

Demonstration Testing

In 1977, a series of flights were made by ORD personnel and private pilots to determine the operating characteristics of Enviropod. These tests were then followed by several indoctrination flights for EPA headquarters personnel and representatives of twelve federal agencies in the Washington area.

Several regional demonstration tests have been completed—in Boston, in New

Comparative Costs

Item	*Enviropod*	*Conventional Aerial Photography*
Film size	70mm	9 inch (228mm)
Type film	color	color
Cameras and equipment provided by	EPA	EPA
Flight Time	$142.50	$550.00
Film	176.12	497.02
Processing	25.07	100.28
Two duplicates of imagery	50.14	200.56
Total	$393.83	$1,347.86

York and Philadelphia, and in Atlanta and Athens, Georgia. Results of these first tests show that Enviropod is especially useful both in documenting nonpoint sources of pollution and in providing a basis for direct action against facilities with stack emissions that do not meet EPA standards. The information gathered can also help to revitalize state monitoring and enforcement programs.

Costs of Operation

Part of the appeal of Enviropod is its cost of operation: the system promises significant cost savings to regional offices as well as to branches of the government other than EPA.

Conventional aerial photography costs range from $165 to $220 per hour compared with Enviropod's cost of $36 per hour. Equivalent coverage of the recent Johnstown flood by Enviropod and by conventional aerial photography showed that there was a substantial cost reduction with Enviropod.

Support to Other Agencies

The U.S. Forest Service uses Enviropod as a useful tool for detection of plant disease and insect infestation. The U.S. Geological Survey can use Enviropod for collection of data to compare with ground measurements in support of their land-use mapping program.

Other agencies expressing interest in the system are the Treasury Department, National Oceanic and Atmospheric Administration, Corps of Engineers, State Department, Soil Conservation Service, Bureau of Land Management, Federal Aviation Administration, and the Civil Air Patrol.

The widespread interest in Enviropod reflects its potential role in producing valuable data for a variety of applications.

The following ORD component contributed to the research described above:

OFFICE OF MONITORING AND TECHNICAL SUPPORT: • Environmental Monitoring and Support Laboratory, Las Vegas, NV

A sample of Enviropod photography

Potential Enviropod Uses.

Enforcement Programs (Discovery and Documentation)	• Emissions • Location of nonfilers • Dredge and fill violations • Thermal discharges-severity and extent
Hazardous Materials	• Location of spills • Storage surveillance
Water Supply	• Reservoir surveillance • Documentation of preferred locations
Field Studies	• Location of sampling points and access routes • Documentation of extent of nuisance weeds or algae growths
Solid Waste	• Location of leachate seeps around landfills • Location of open dump or unauthorized landfills
Environmental Impacts	• Existing land use • Imagery for use in Environmental Impact Statements

cheese whey

ORD develops some innovative ways to recover useful products from a major industrial waste

Whey is a green-yellow liquid that is a by-product of all cheese production. Its characteristics differ depending on whether cheeses are made from skim milk or natural milk. The skim milk cheeses, like cottage cheese, yield an acid whey; the whole milk cheeses, like cheddar, yield a sweet whey. For every 10 pounds of cheese made, 60 pounds of whey are produced. On a national scale that represents approximately 30 billion pounds of fluid whey at 6% to 7% solids.

As a by-product high in lactose and protein, whey is a resource awaiting discovery. At this point, however, it is still a significant waste problem necessitating proper treatment.

Over the years, ORD has studied whey treatment to facilitate economical by-product recovery and new product development. Major efforts yielding results include:

- Fermentation for alcoholic beverage production.
- Separation of cheese whey components by membrane technology.
- Fermentation for protein production.
- Spray drying to a protein-rich powder.

Fermenting Cheese Whey

Wine from Whey

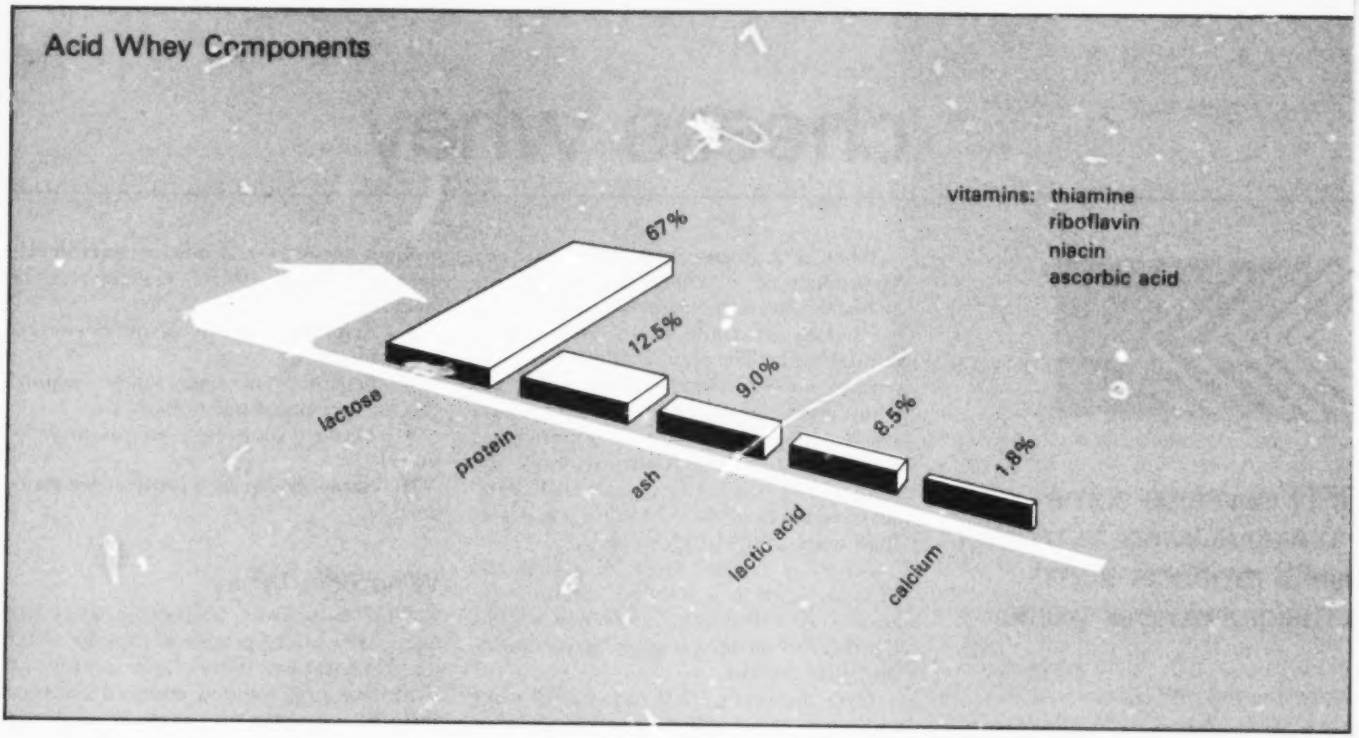
Wine made from fermenting whey has been successfully produced through ORD experimentation. Very little energy or expensive equipment is required since no removal of water is necessary and the entire whey is used. The process has been explored on both laboratory and pilot plant scales.

First, the protein is removed from the whey and enough dextrose is added to assure proper alcohol levels. Just before fermentation is started, sulfur dioxide is added for stability. The whey is then inoculated with yeast and allowed to ferment. After fermentation, the wine is aged and clarified. Fruit flavors may be added and the wine may be sweetened. If the product is accepted by the public, wine production holds a promising future for cheesemakers.

Recovering Lactose, Protein

Pressurized membrane processes to extract lactose and protein from whey have been explored for several years. By 1977, a two-step approach had evolved to be the most effective.

First, ultrafiltration, a low pressure operation, is used to separate the larger molecules (in this case, whey protein). Passing the whey through the ultrafiltration unit separates it into two streams. In one stream the protein is concentrated twelvefold to 8%. The other stream is then pumped into a reverse osmosis unit, where high pressures separate out the smaller lactose molecules and dissolved solids. The lactose undergoes a fourfold increase in concentration to 25%. The permeate that remains is relatively pure water.



At a processing capacity of 300,000 pounds of whey per day, this system recovers up to 95% of the biodegradable organics. The protein concentrate can be used in food products. The lactose stream can be further concentrated to about 50% solids and used as animal feed.

Protein Production

Under controlled conditions, a high protein (35% to 50%) fermented mass suitable for animal feed can be produced using condensed whey. Applications seem most favorable for large rural facilities. Also, the potential exists for harvesting food-grade yeast.

The difficulties encountered in drying acid whey have been the primary deterrent to development of this by-product as a food ingredient. Recent ORD research, however, shows that spray-drying technology appears feasible.

With the world's growing need for protein, the treatment of whey as a resource instead of as a waste problem becomes increasingly practical. Imaginative research has brought whey technology to the point where its potential commercial uses can yield profits rather than problems.

Taste Test for Whey Wines

	Number of Tasters	*Scale of 1 to 10*
Raspberry-whey, sweetened	126	6.9
Strawberry-whey, sweetened	25	6.4
Blackberry-whey, sweetened	25	6.4
Whey, clear, sweetened	145	6.3
Whey, citrus-flavored, sweetened	50	5.5
Whey, cloudy, sweetened	109	5.2
Pear-whey, sweetened	25	4.7
Apple-whey, sweetened	25	4.6
Whey, clear, unsweetened	36	3.8

The following ORD component contributed to the research described above:

OFFICE OF ENERGY, MINERALS AND INDUSTRY: • Industrial Environmental Research Laboratory, Cincinnati, OH (Corvallis)

information

ORD puts new emphasis on providing information for environmental decisions

EPA provides much of the scientific data used in establishing and implementing national environmental policy. The analytical methods that ORD generates must receive timely dissemination if they are to be integrated effectively into the environmental decision-making process. Transferring technical information effectively has become a monumental task as the depth and breadth of research have grown. Successful transfer requires far more than the mere distribution of research reports. Instead, it is necessary to match available information carefully with the needs of different users.

Until last year, responsibility within ORD for the transfer of technical information was organizationally fragmented. Information transfer was based on technical reports. Building on input from the users of EPA data, however, a new program was put into action. In FY 1976, ORD established a technical information program, which includes all standard report dissemination actions, but whose principal goal is active information transfer of the findings of the entire spectrum of ORD programs. In early 1977, the Environmental Research Information Center (ERIC) was established in Cincinnati. The Center is devoted to distributing environmental information and research data to serve the needs of other federal agencies, state and local officials, and the public at large.

ERIC's staff has conducted more than 130 seminars throughout the United States and its territories, and has exhibited its products at many state fairs, conferences, and professional society meetings. ERIC has prepared publications, including motion pictures, and more than 2,000,000 copies have been distributed to date. Eleven special reports and more than 600 scientific and technical reports were published in 1977.

The ERIC staff produces both general and specific reports. There are process design manuals for the engineer/designer; capsule reports of demonstration projects; industrial seminar publications for plant managers and engineers; reports on research projects for the scientific and technical community; and brochures and the summary briefing publications for executives.

ERIC is investigating better communication techniques via an agreement with the Environmental Extension Project at Oklahoma State University. The project is developing techniques for transferring information to state and local level environmental agencies through the Cooperative Extension Service. This pilot project has been successfully tested in Oklahoma, and similar tests are anticipated for the 10 federal regions, with the goal of making environmental information accessible to state and local environmental authorities.

The EPA technical information program is still in its infancy, but plans for the future include more extensive coverage of ORD research areas. As information becomes increasingly abundant, the efforts of ERIC will become an even more important component of the ORD research process.

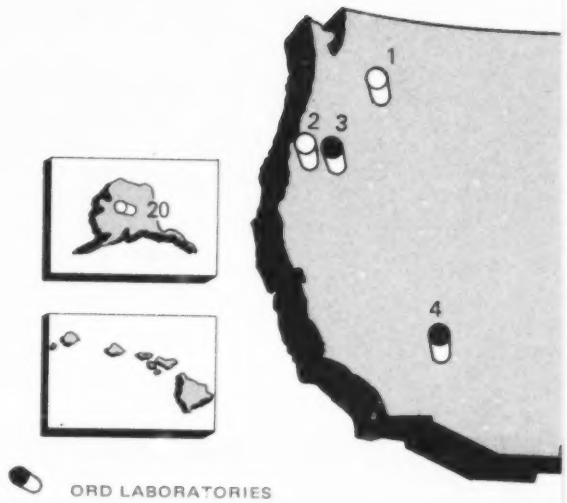
The following ORD component contributed to this section.

OFFICE OF MONITORING AND TECHNICAL SUPPORT: • Environmental Research Information Center, Cincinnati, OH

ORD resources

Fiscal Year 1977 - - $237.7 millions
1,886 People

ORD funding by function or programmatic categories	$M
Health Effects	28.2
Ecological Processes & Effects	17.9
Transport & Fate of Pollutants	13.3
Stratospheric Modification	2.5
Minerals Processing & Manufacturing	13.1
Renewable Resources	6.2
Waste Management	14.2
Water Supply	13.8
Environmental Management	1.4
Measurement Techniques & Equipment	4.0
Characterization/Measurement Methods	8.1
Quality Assurance	4.8
Technical Support	11.3
Energy Extraction & Processing	25.4
Energy Conservation, Use and Assessment	33.4
Energy-Environmental Effects	33.1
Other	7.0
Total	237.7



ORD LABORATORIES

OTHER ORD FACILITIES

1 - WENATCHEE, WASHINGTON (OHEE)

2 - NEWPORT, OREGON (OHEE)

3 - CORVALLIS, OREGON
Environmental Research Lab. (OHEE)

4 - LAS VEGAS, NEVADA
Environmental Monitoring and Support Lab. (OMTS)

5 - ADA, OKLAHOMA
Robert S. Kerr Environmental Research Lab. (OALWU)

6 - GULF BREEZE, FLORIDA
Environmental Research Lab. (OHEE)

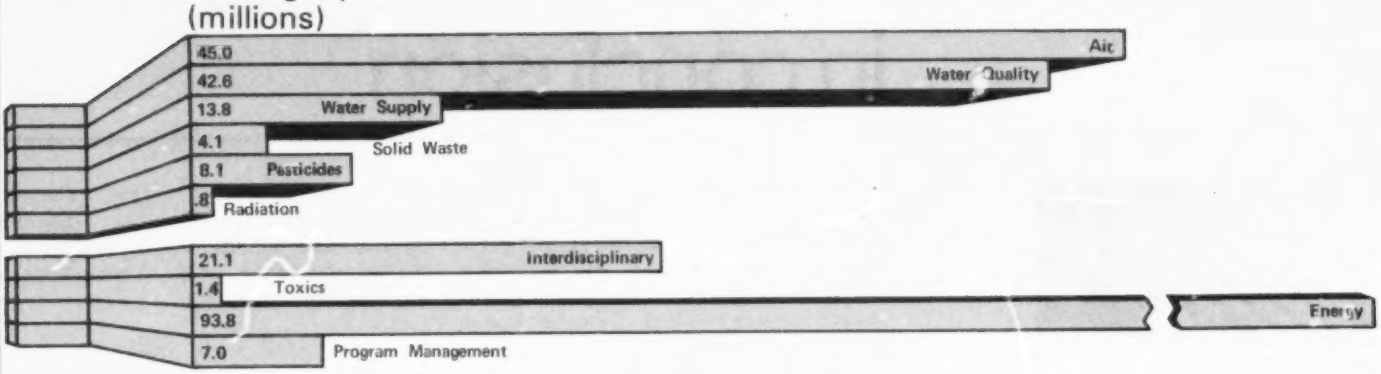
7 - ATHENS, GEORGIA
Environmental Research Lab. (OALWU)

8 - BEARS BLUFF, SOUTH CAROLINA (OHEE)

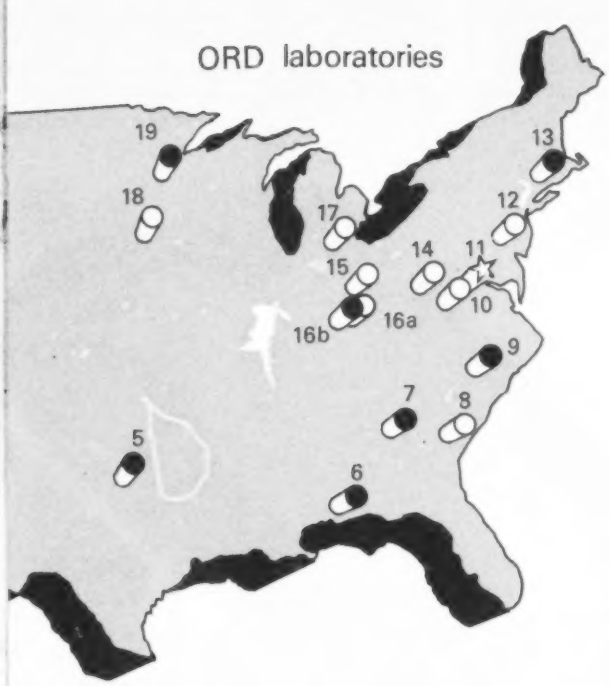
9 - RESEARCH TRIANGLE PARK, N.C.
Environmental Monitoring and Support Lab. (OMTS)
Industrial Environmental Research Lab. (OEMI)
Environmental Sciences Research Lab. (OALWU)
Health Effects Research Lab. (OHEE)

10 - WARRENTON, VIRGINIA (OMTS)

Funding by Media (millions)



ORD laboratories



☆11 - WASHINGTON, D.C.
Headquarters, OR&D

12 - EDISON, NEW JERSEY (OEMI)

13 - NARRAGANSETT, RHODE ISLAND
Environmental Research Lab. (OHEE)

14 - RIVESVILLE, WEST VIRGINIA
(OEMI)

15 - LEBANON, OHIO (OALWU)

16a - NEWTOWN, OHIO (OHEE)

16b - CINCINNATI, OHIO
Environmental Monitoring and Support Lab. (OMTS)
Industrial Environmental Research Lab. (OEMI)
Municipal Environmental Research Lab. (OALWU)
Health Effects Research Lab. (OHEE)
Environmental Research Information Center (OMTS)

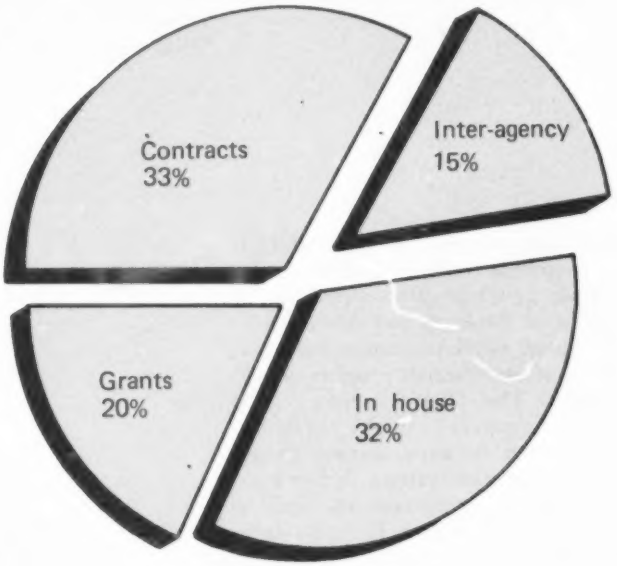
17 - GROSSE ILE, MICHIGAN (OHEE)

18 - MONTICELLO, MINNESOTA
(OHEE)

19 - DULUTH, MINNESOTA
Environmental Research Lab. (OHEE)

20 - COLLEGE, ALASKA (OHEE)

Funding by Mechanism



Funding by Appropriation

	$M
Research & Development	237.3
Abatement & Control	.4
Total	237.7

The Organization

ORD is managed out of its Washington, D.C. headquarters through four major offices: Health and Ecological Effects (OHEE); Energy, Minerals and Industry (OEMI); Air, Land and Water Use (OALWU); and Monitoring and Technical Support (OMTS). Each of these offices has associated laboratories as indicated in the accompanying map.

in conclusion

The past year's highlights are prologue to an increased effort in 1978.

The results described in this highlights report represent but a handful of the more than 1,900 projects supported by the Office of Research and Development in 1977. Even within this report, however, the range of our research program should be evident. The ORD program ranges from direct support to EPA's regulatory functions, such as cancer assessment and drinking water purification, to investigations of long-term phenomona, such as the ozone layer analyses. It ranges from technologies to clean up car exhausts to technologies to clean up power plant fumes, and from studies of how cells react to carcinogens to studies of how people react to energy development activities.

As for 1978, it promises to be a productive year for ORD. Here is a preview of some of the achievements we expect to report.

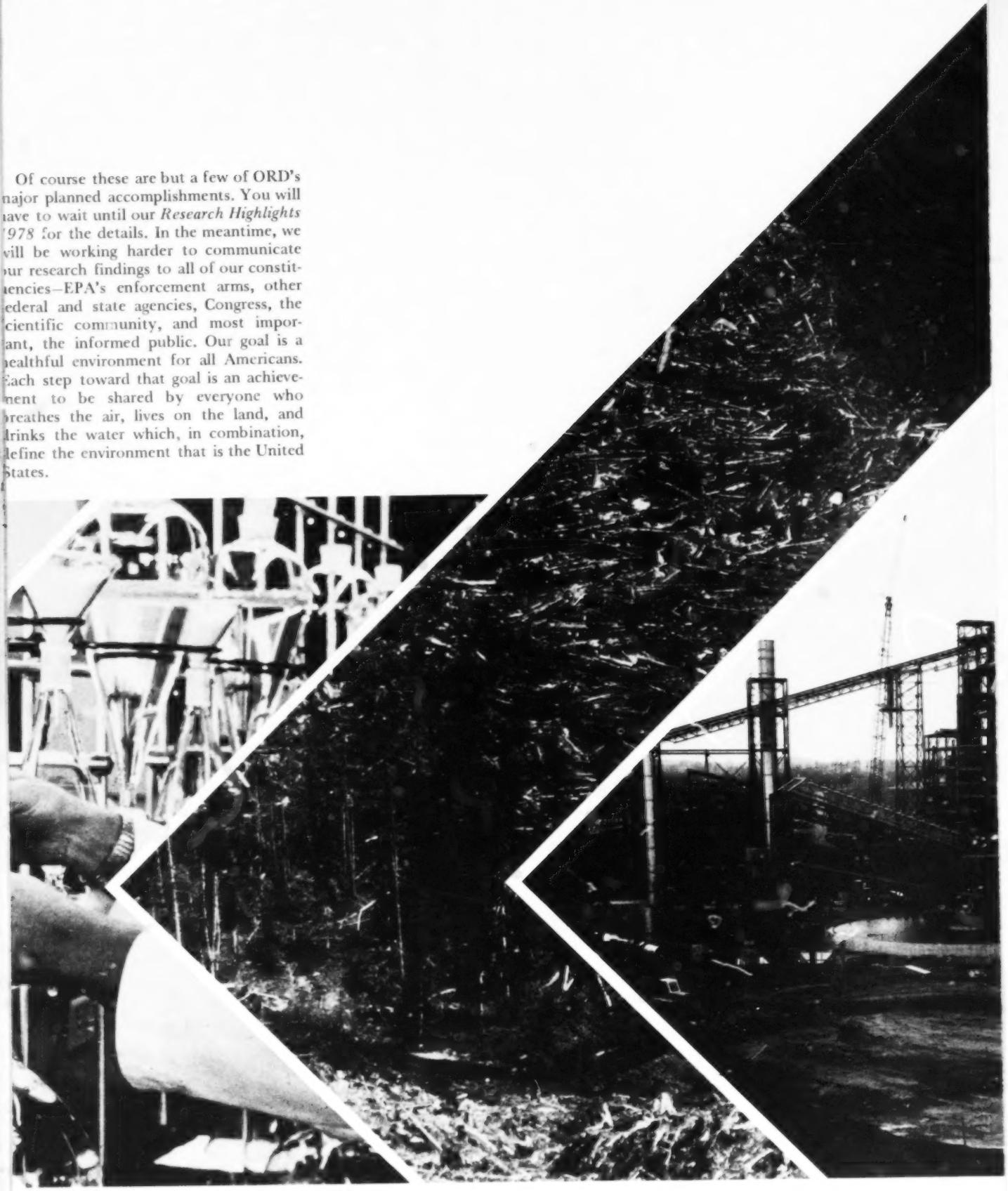
In the energy/environment area we will complete the testing of an industrial-scale desulfurization scrubber. A coal-burning 30-megawatt-equivalent boiler at Rickenbacker Air Force Base, Columbus, Ohio, is the site. If successful, the test will prove the availability of scrubber control technology for industrial boilers—an accomplishment that is important if coal use is to be increased in the industrial sector without severe degradation of air quality.

Also related to energy production is a test which will be conducted in San Benito, Texas, in 1978. This ORD-sponsored demonstration will determine whether a chemically active fluidized bed system burning residual oil can be used to drive a plant formerly run on natural gas. If successful, this demonstration may provide yet another method of substituting "dirty" fuel (i.e., residual oil) for natural gas without sacrificing clean air.

As you have learned from the chapter on drinking water, the present method of disinfecting water supplies—chlorination—may create potentially hazardous pollutants known as organochlorides. In 1978, ORD will seek practical alternatives to the chlorination process. One specific alternative—treatment with chlorine dioxide—will undergo exhaustive testing. We will present the results of these tests in our next highlights report.

Finally, with water quality concerns now focused on the more subtle toxics—low concentrations of highly dangerous substances in our water supplies—our 1978 program will test a technology that may help to keep these toxics from ever reaching our water in the first place. Most of these toxics come from industrial effluent streams. Activated charcoal devices may be able to remove the toxics before these streams are discharged.

Of course these are but a few of ORD's major planned accomplishments. You will have to wait until our *Research Highlights 1978* for the details. In the meantime, we will be working harder to communicate our research findings to all of our constituencies—EPA's enforcement arms, other federal and state agencies, Congress, the scientific community, and most important, the informed public. Our goal is a healthful environment for all Americans. Each step toward that goal is an achievement to be shared by everyone who breathes the air, lives on the land, and drinks the water which, in combination, define the environment that is the United States.



:he people

At ORD, information is our only product, and people are our most important resource. We have more than 1800 employees within r 16 laboratories nationwide and our Washington, D.C. headquarters. Those listed here are not the only individuals who are niliar with the topics cited. The following individuals were selected because of their accessibility to the public and their broad owledge of the subject area. You are invited to call them with your questions.

Subject	*Contact*	*Organization*	*Telephone*
Sulfates	Paul Altshuller	ESRL-RTP	919 541-2191
—Transport	William Wilson	ESRL-RTP	919 541-2551
—Control	Richard Stern	IERL-RTP	919 541-2578
—Coal-Cleaning	James Kilgroe	IERL-RTP	919 541-2851
Kepone —Impacts	Tudor Davies	ERL-Gulf Breeze	904 932-5311
—Control	Paul DesRosiers	OEMI-HQ	202 755-9014
Drinking Water	Lawrence Gray	OALWU-HQ	202 426-0287
NO_x —Health	John Knelson	HERL-RTP	919 541-2531
—Transport	Paul Altshuller	ESRL-RTP	919 541-2191
—Control	Joshua Bowen	IERl-RTP	919 549-2470
Geothermal	Greg D'Alessio	OEMI-HQ	202 426-4568
Ozone	Alphonse Forziati	OHEE-HQ	202 245-3029
Cancer	Elizabeth Anderson	ORD-HQ	202 755-3968
Cancer	Robert McGaughy	ORD-HQ	202 755-3968
Clean Cars	Stanley Blacker	OHEE-HQ	202 755-9722
Enviropod	Vernard Webb	EMSL-L.V.	703 347-6224
Toxics	Paul DesRosiers	OEMI-HQ	202 755-9014
Spills	Ira Wilder	IERL-Cin.	201 321-6635
Ohio River	Lowell Smith	OEMI-HQ	202 755-2737
Cheese Whey	Clinton Parker	IERL-Cin.	513 684-4227
Energy from Waste	George Huffman	IERL-Cin.	513 684-4363
Energy from Waste	Carlton Wiles	MERL-Cin.	513 684-7881
Coke Ovens	Norm Plaks	IERL-RTP	919 541-2733
Agriculture	Darwin Wright	OALWU-HQ	202 426-2407
Municipal Waste	William Rosenkranz	OALWU-HQ	202 426-2260
Energy Futures	Lowell Smith	OEMI-HQ	202 755-2737
Information	Robert Crowe	ERIC-Cin.	513 684-7391

Credits for this report: Richard Laska, Don Risher, David Meyers, Jack Ballestero, Linda Smith, Cal Lawrence.